U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-279 357

Municipal Sludge Agricultural Utilization Practices An Environmental Assessment. Volume II

SCS Engineers, Long Beach, Calif

Prepared for

Environmental Protection Agency, Washington, D C Office of Solid Waste

1978

PB 279 357

MUNICIPAL SLUDGE AGRICULTURAL UTILIZATION PRACTICES

An Environmental Assessment

Volume II

Volume I which presents: an explanation of the purposes and methodology for site selection; a detailed explanation of the sampling and analytical program; an analysis of the data; and a summary, conclusions, and recommendations section will be available from Solid Waste Information, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268

U.S. ENVIRONMENTAL PROTECTION AGENCY

1978

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA/530/SW-156c

2.

3. Recipient's Accession No.

4. Title and Subtitle

Municipal Sludge Agricultural Utilization Practices-
An Environmental Assessment

5. Report Date 1978

6.

7. Author(s)

K.V. LaConde, R.J. Lofy, and R.P. Stearns

8. Performing Organization Rept. No. PB279357

9. Performing Organization Name and Address

SCS Engineers
4014 Long Beach Boulevard
Long Beach, California

10. Project/Task/Work Unit No.

11. Contract/Grant No. 68-01-3265

12. Sponsoring Organization Name and Address

United States Environmental Protection Agency
Office of Solid Waste
Washington, D. C. 20460

13. Type of Report & Period Covered

Final Report

14. 200/01

15. Supplementary Notes

16. Abstracts

An environmental assessment was performed at nine study sites across the United States to investigate the effects of utilizing municipal wastewater treatment plant sludge for agricultural purposes. The sites represented a wide range of sludge applications rates, sludge characteristics, cropping practices, soils, population densities, and climatological and geographical conditions. The assessment included evaluative criteria such as chemical, physical, and microbiological constituents of sludges; surface and subsurface soil properties including presence and accumulation of heavy metals, pesticides, nutrients, bacteria, and parasites; plant characteristics including heavy metal and pesticide uptake, and potential contamination by bacteria and parasites; public attitudes; landspreading costs (capital and operational); current and past operating procedures; and management practices at each of the nine sites.

17. Key Words and Document Analysis. 17a. Descriptors

Costs, environmental impacts, practices, chemical composition, soil, plants, cadmium, copper, nickel, lead, zinc, chlorinated hydrocarbons, pathogens, groundwater

17b. Identifiers/Open-Ended Terms

Landspreading, sewage sludge

17c. COSATI Field/Group

18. Availability Statement

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 437

22. Price A19 - A01

This report was prepared by SCS Engineers, Inc., Long Beach, California, under Contract No. 68-01-3265.

Publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement by the U.S. Government.

An environmental protection publication (SW-156c) in the solid waste management series.

TABLE OF CONTENTS

Page

List of Tables v
List of Figures x
List of Photographs xi

CHAPTER I - MACON, GEORGIA 1
- Site Description 1
- Climate 5
- Soil Description 6
- Source and Description of Sludge 12
- Public Attitudes toward Landspreading of Sludge 19
- State and Local Regulations on Sludge Spreading 23
- Economics 23
- Sampling and Analysis 24

CHAPTER II - LAS VIRGENES, CALIFORNIA 48
- Site Description 48
- Climate 56
- Soil Description 57
- Source and Description of Sludge 61
- Public Attitudes toward Landspreading of Sludge 68
- State and Local Regulations on Sludge Spreading 71
- Economics 71
- Sampling and Analysis 72

CHAPTER III - WILMINGTON, OHIO 93
- Site Description 93
- Climate 98
- Soil Description 99
- Source and Description of Sludge 106
- Public Attitudes toward Landspreading of Sludge 112
- State and Local Regulations on Sludge Spreading 112
- Economics 117
- Sampling and Analysis 118

CHAPTER IV - SPRINGFIELD, MISSOURI 142
- Site Description 142
- Climate 147
- Soil Description 148
- Source and Description of Sludge 153
- Public Attitudes toward Landspreading of Sludge 165
- State and Local Regulations on Sludge Spreading 166
- Economics 167
- Sampling and Analysis 168

TABLE OF CONTENTS (Continued)

Page

CHAPTER V - CHIPPEWA FALLS, WISCONSIN 192
Site Description 192
Climate 198
Soil Description 199
Source and Description of Sludge 204
Public Attitudes toward Landspreading of Sludge 213
State and Local Regulations on Sludge Spreading 216
Economics 219
Sampling and Analysis 219

CHAPTER VI - HOPKINSVILLE, KENTUCKY 243
Site Description 243
Climate 248
Soil Description 250
Source and Description of Sludge 252
Public Attitudes toward Landspreading of Sludge 263
State and Local Regulations on Sludge Spreading 264
Economics 264
Sampling and Analysis 265

CHAPTER VII - FRANKFORT, INDIANA 287
Site Description 287
Climate 291
Soil Description 292
Source and Description of Sludge 296
Public Attitudes toward Landspreading of Sludge 303
State and Local Regulations on Sludge Spreading 306
Economics 307
Sampling and Analysis 308

CHAPTER VIII - KENDALLVILLE, INDIANA 331
Site Description 331
Climate 337
Soil Description 338
Source and Description of Sludge 342
Public Attitudes toward Landspreading of Sludge 350
State and Local Regulations on Sludge Spreading 354
Economics 354
Sampling and Analysis 355

CHAPTER IX - COLUMBUS, INDIANA 377
Site Description 377
Climate 382
Soil Description 383
Source and Description of Sludge 388
Public Attitudes toward Landspreading of Sludge 397
State and Local Regulations on Sludge Spreading 400
Economics 400
Sampling and Analysis 400

TABLES

Number and Title Page

1. Macon, Georgia Meteorological Data 7
2. Chemical and Physical Properties of Soils, Macon, Georgia 11
3. Macon, Georgia Secondary Effluent Treatment Efficiencies 14
4. Macon, Georgia Stabilized Liquid Sludge Analysis 16
5. Macon, Georgia Liquid Sludge Handling 18
6. Macon, Georgia Operation and Maintenance Costs for Sludge Spreading 25
7. Cost for Disposal of Sludge 26
8. Chemical Characterization of Stabilized Sludges 29
9. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils 30
10. Total Metal Concentrations in Individual Sub-Surface Soil Samples 31
11. Metal Concentrations in Surface Soils and Plants 32
12. Selenium in Composite Plants and Soils 33
13. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants 44
14. Parasites in Sludges, Soils, and Plants 45
15. Concentrations of Microbes in Sludges, Soils and Plants 46
16. Tapia Water Reclamation Plant 1975 Chemical Analysis Summary Secondary Effluent 54
17. Las Virgenes, California Sludge Disposal 55
18. Las Virgenes, California Meteorological Data 58
19. Chemical and Physical Properties of Soils, Las Virgenes, California 62
20. Las Virgenes, California Stabilized Liquid Sludge Analysis 65
21. Las Virgenes, California Dewatered Sludge Generation 66
22. Las Virgenes, California Digestion, Dewatering, and Spreading Costs 73
23. Cost for Disposal of Dewatered Sludge - 1975 74
24. Chemical Characterization of Stabilized Sludges 77
25. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils 78
26. Total Metal Concentrations in Individual Sub-surface Soil Samples 79
27. Metal Concentrations in Surface Soils and Plants 80
28. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants 89
29. Parasites in Sludges, Soils, and Plants 90

TABLES (Continued)

Number and Title — Page

30. Concentration of Microbes in Sludges, Soils, and Plants 91
31. Wilmington, Ohio Meteorological Data 100 — Ohio
32. Chemical and Physical Properties of Soils, Wilmington, Ohio 105
33. Wilmington, Ohio Secondary Effluent Treatment Efficiencies 107
34. Wilmington, Ohio Stabilized Liquid Sludge Analysis 110 — Ohio
35. Wilmington, Ohio Liquid Sludge Hauling 111
36. Wilmington, Ohio Estimated Labor and Fuel Costs 119
37. Cost for Disposal of Liquid Sludge 1975 120
38. Chemical Characterization of Stabilized Sludges from Wilmington, Ohio 123
39. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soil 124
40. Total Metal Concentrations in Individual Subsurface Soil Samples 125
41. Metal Concentrations in Surface Soils and Plants 126
42. Molybdenum in Composite Plants and Soils 127
43. Chlorinated Hydrocarbon Concentrations in Sludge, Soils and Plants 138
44. Parasites in Sludges, Soils, and Plants 139
45. Concentration of Microbes in Sludges, Soils, and Plants 140
46. Springfield, Missouri Application Rates 146
47. Springfield, Missouri Meteorological Data 149
48. Chemical and Physical Properties of Soils, Springfield, Missouri 154
49. Sprinfield, Missouri Industrial Flows 158
50. Springfield, Missouri Stabilized Liquid Sludge Analyses 160 — [illegible]
51. Springfield, Missouri Liquid Sludge Hauling Quantities 161
52. Cost for Disposal of Liquid Sludge 169
53. Chemical Characterization of Stabilized Sludges from Springfield, Missouri 172
54. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils 173
55. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils (Backhoe Trench) 174
56. Total Metal Concentrations in Individual Subsurface Soil Samples 175

TABLES (Continued)

Number and Title Page

57. Molybdenum in Composite Plants and Soils 176
58. Metal Concentrations in Surface Soils and Plants 177
59. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants 188
60. Parasites in Sludges, Soils, and Plants 189
61. Concentration of Microbes in Sludges, Soils, and Plants 190
62. Chippewa Falls Sludge Application Rates 196
63. Chippewa Falls, Wisconsin Meteorological Data 200
64. Chemical and Physical Properties of Soils, Chippewa Falls, Wisconsin 205
65. Chippewa Falls Secondary Effluent Treatment Efficiencies 207
66. Chippewa Falls Industrial Flows 208
67. Chippewa Falls Stabilized Liquid Sludge Analyses 210
68. Chippewa Falls Liquid Sludge Distribution 211
69. Chippewa Falls Sludge to Drying Beds 212
70. Chippewa Falls Capital Expenditures 220
71. Cost for Disposal of Liquid Sludge 221
72. Chemical Characterization of Stabilized Sludges from Chippewa Falls, Wisconsin 224
73. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils 225
74. Total Metal Concentrations in Individual Subsurface Soil Samples 226
75. Metal Concentrations in Surface Soils and Plants 227
76. Metal Concentrations in Soy Bean Samples 228
77. Chlorinated Hydrocarbon Concentrations in Sludges, Soils, and Plants 239
78. Parasites in Sludges, Soils, and Plants 240
79. Concentration of Microbes in Sludges, Soils, and Plants 241
80. Hopkinsville, Kentucky Climatological Summary 249
81. Chemical and Physical Properties of Soils, Hopkinsville, Kentucky 253
82. Hopkinsville, Kentucky Secondary Effluent Treatment Facilities 255
83. Hopkinsville, Kentucky Industrial Flows 256
84. Stabilized Liquid Sludge Analysis 258
85. Hopkinsville, Kentucky Sludge Generation 260
86. Cost for Disposal of Liquid Sludge 266
87. Chemical Characterization of Stabilized Sludges from Hopkinsville, Kentucky 269

TABLES (Continued)

Number and Title	Page
88. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils	270
89. Total Metal Concentrations in Individual Subsurface Soil Samples	271
90. Metal Concentrations in Surface Soils and Plants	272
91. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants	283
92. Parasites in Sludges, Soils, and Plants	284
93. Concentration of Microbes in Sludges, Soils, and Plants	285
94. Frankfort, Indiana Climatological Data	293
95. Chemical and Physical Properties of Soils, Frankfort, Indiana	297
96. Frankfort, Indiana STP Wastewater Operating Summaries	298
97. Frankfort, Indiana Stabilized Liquid Sludge Analyses	300
98. Frankfort, Indiana Industrial Flows	301
99. Cost for Disposal of Liquid Sludge	309
100. Chemical Characterization of Stabilized Sludges from Frankfort, Indiana	312
101. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils	313
102. Total Metal Concentrations in Individual Surface Soil Samples	314
103. Metal Concentrations in Surface Soils and Plants	315
104. Metal Concentrations in Wheat Grain Samples	316
105. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants	327
106. Parasites in Sludges, Soils, and Plants	328
107. Concentration of Microbes in Sludges, Soils, and Plants	329
108. Kendallville, Indiana Sludge Application Rates	336
109. Kendallville, Indiana meteorological Data	339
110. Chemical and Physical Properties of Soils	343
111. Kendallville, Indiana Secondary Effluent Treatment Efficiencies	345
112. Kendallville, Indiana Stabilized Sludge Analyses	
113. Kendallville, Indiana Sludge Generation	349
114. Chemical Characterization of Stabilized Sludges from Kendallville, Indiana	358
115. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils	359

TABLES (Continued)

Number and Title | Page

116. Total Metal Concentrations in Individual Subsurface Soil Samples 360
117. Selenium in Composite Plants and Soils 361
118. Metal Concentrations in Surface Soils and Plants 362
119. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants 373
120. Parasites in Sludges, Soils, and Plants 374
121. Concentration of Microbes in Sludges, Soils, and Plants 375
122. Columbus, Indiana Meteorological Data 384
123. Chemical and Physical Properties of Soils, Columbus, Indiana 389
124. Columbus, Indiana Secondary Effluent Treatment Efficiencies 390
125. Industrial Discharge Parameters 391
126. Columbus, Indiana Liquid Stabilized Sludge Analyses 393
127. Columbus, Indiana Sludge Generation 395
128. Columbus, Indiana Sludge Application Rates 396
129. Columbus, Indiana Capital Expenditures 401
130. Columbus, Indiana Liquid Sludge Spreading Costs 402
131. Cost for Disposal of Liquid Sludge 403
132. Chemical Characterization of Stabilized Sludges 407
133. Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils 408
134. Total Metal Concentrations in Individual Subsurface Soil Samples 409
135. Metal Concentrations in Surface Soils and Plants 410
136. Metal Concentrations in Corn Grain Samples 411
137. Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants 422
138. Parasites in Sludges, Soils, and Plants 423
139. Concentration of Microbes in Sludges, Soils, and Plants 424

FIGURES

Number and Title		Page
1.	Macon, Georgia Treated Plot	2
2.	Macon, Georgia Control Plot	4
3-12.	Particle Size Analyses	34-43
13.	Las Virgenes, California Treated Plot	50
14.	Las Virgenes, California Control Plot	51
15-22.	Las Virgenes, California Particle Size Analyses	81-88
23.	Wilmington, Ohio	94
24.	Wilmington Treated Plot	95
25.	Wilmington Control Plot	96
26-35.	Wilmington, Ohio Particle Size Analyses	128-137
36.	Springfield, Missouri Treated Plot	143
37.	Springfield, Missouri Control Plot	144
38-47.	Springfield, Missouri Particle Size Analyses	178-187
48.	Chippewa Falls, Wisconsin Treated Area	193
49.	Chippewa Falls, Wisconsin Control Area	194
50-59.	Chippewa Falls, Wisconsin Particle Size Analyses	229-238
60.	Hopkinsville, Kentucky Treated Plot	244
61.	Hopkinsville, Kentucky Control Plot	246
62-71.	Hopkinsville, Kentucky Particle Size Analyses	273-282
72.	Frankfort, Indiana Treated Plot	288
73.	Frankfort, Indiana Control Plot	289
74-83.	Frankfort, Indiana Particle Size Analyses	317-325
84.	Kendallville, Indiana Treated Field	332
85.	Kendallville, Indiana Control Field	334
86-95.	Kendallville, Indiana Particle Size Analyses	363-372
96.	Columbus, Indiana Treated Field	378
97.	Columbus, Indiana Control Field	380
98-107.	Columbus, Indiana Particle Size Analyses	412-421

PHOTOGRAPHS

Number and Title	Page
1. Treated Site	20
2. Treated Site Plants	20
3. Control Site	21
4. Control Site Plants	21
5. S.T.P. Drying Beds	22
6. S.T.P. Tank Truck	22
7. Treated Plot	69
8. Control Plot	69
9. DCG Dewatering Unit	70
10. Dumpster	70
11. Treated Field	113
12. Control Field	113
13. Drying Beds	114
14. Sludge Spreading Tank	114
15. Close-up, Baffle Arrangement	115
16. Treated Field	163
17. Fescue, Treated Field	163
18. Backhoe Trench, Treated Field	164
19. Control Field	164
20. Treated Field	214
21. Trifoliate	214
22. Bed Dried Sludge	215
23. Tank Truck	215
24. Treated Plot	261
25. Control Field	261
26. Drying Beds	262
27. Sludge Tank Truck	262
28. Treated Field	304
29. Control Field	304
30. Sludge Tank Truck	305
31. Drying Beds	305
32. Sludge on Treated Field	351
33. Treated Plot	351
34. Control Plot	352
35. Sludge Spreading Truck	352
36. Alfalfa Treated Plot	353
37. Treated Field	398
38. Tank Truck Depositing Sludge	398
39. Sludge Saturated Ground	399

(12 blank)

CHAPTER I

MACON, GEORGIA

SITE DESCRIPTION

Location

This study site is located on the east side of Macon, Georgia, approximately 5 km (3 mi) from the downtown area. Both the sludge treated plot and the Lower Poplar Street Sewage Treatment Plant (STP) are situated on city-owned property totaling 50.6 ha (125 acres). The western boundary of the property is formed by the Ocmulgee River levee. Sludge generated by the STP has generally been spread on all available land at the site. The treated plot selected for sampling was located in a 12.1 ha (30 acre) field approximately 150 m (500 ft) to the west of the digesters (see Figure 1).

Physical Conditions

The site is relatively level and covered with native grasses. Adjacent land is a mixture of swamps and hardwood forests. The western edge of the treated plot slopes gently to a small 2 ha (5 acre) lake. The groundwater table at the site is approximately 1.5 m (5 ft) below ground surface.

The treated plot has been and continues to be in natural vegetation. In the spring time, cheatgrass (*Bromus tectorum*) abounds. Growth is aided by relatively uniform precipitation. The cheatgrass, after spring harvest, begins to die off. Local bermuda grass then assumes a vigorous growth pattern until the onset of winter.

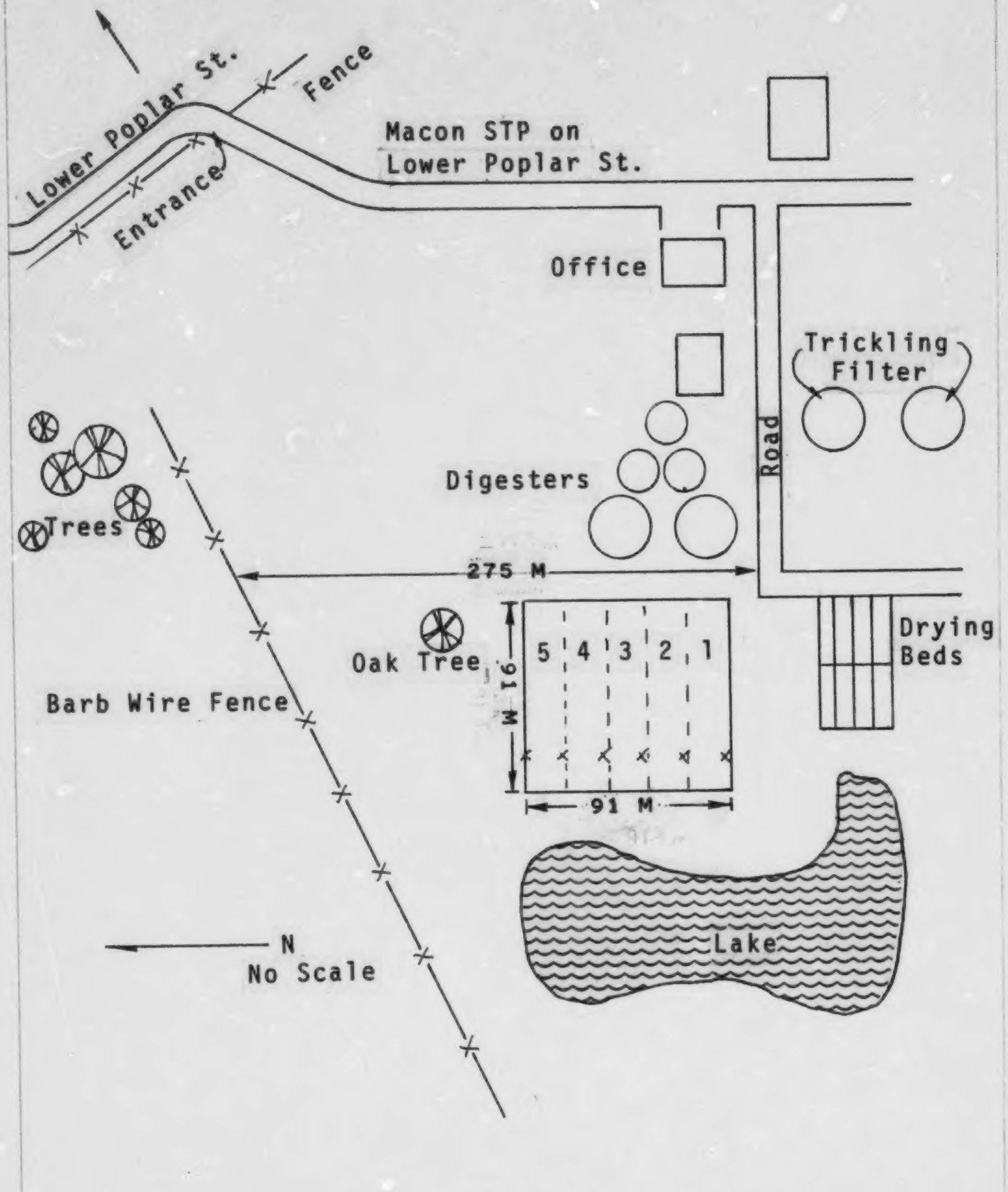

Lower Poplar St.
Fence
Entrance
Macon STP on
Lower Poplar St.
Office
Trickling
Filter
Road
Digesters
Trees
275 M
Oak Tree
5
4
3
2
1
91 M
91 M
Drying
Beds
Barb Wire Fence
Lake
N
No Scale

Figure 1 Macon, Georgia Treated Plot

14

The control plot was adjacent to the STP (see Figure 2) and located near the north end of a 10.1 ha (25 acre) field. It was planted in oats (*Avena sp.*), and its topography and soil characteristics were virtually identical to that of the treated plot. Oats were considered to be sufficiently similar to the cheatgrass to serve as a control crop. The oats had not started to bud and were at the same height - 46 to 61 cm (18 to 24 in) - as the cheatgrass.

Farming Practices

Liquid sludge has been spread on the treated plot and much of the surrounding STP property continuously since 1965. Sludge generation records, however, have been maintained only since 1972 and are not field specific. The STP superintendent estimated that the treated plot has had four uniform and consistent applications of sludge annually since 1965. The estimated average annual application rate has been 28 dry m tons/ha (12.5 dry tons/acre) assuming that the sludge solids content is 11.4 percent (averaged analytical data), and that one load covers 836 sq m (9,000 sq ft).

At the time of sampling (April 5, 1976), the cheatgrass was in vigorous growth. The approximate 0.8 ha (2 acre) treated plot had a uniform stand ranging from 46 to 61 cm (18 to 24 in). The depth of the root zone was approximately 13 to 18 cm (5 to 7 in).

The treated field is leased to a local farmer for production of hay. He pays the STP $0.25 per harvested bale. Normal harvest patterns result in three cuttings annually. The first,

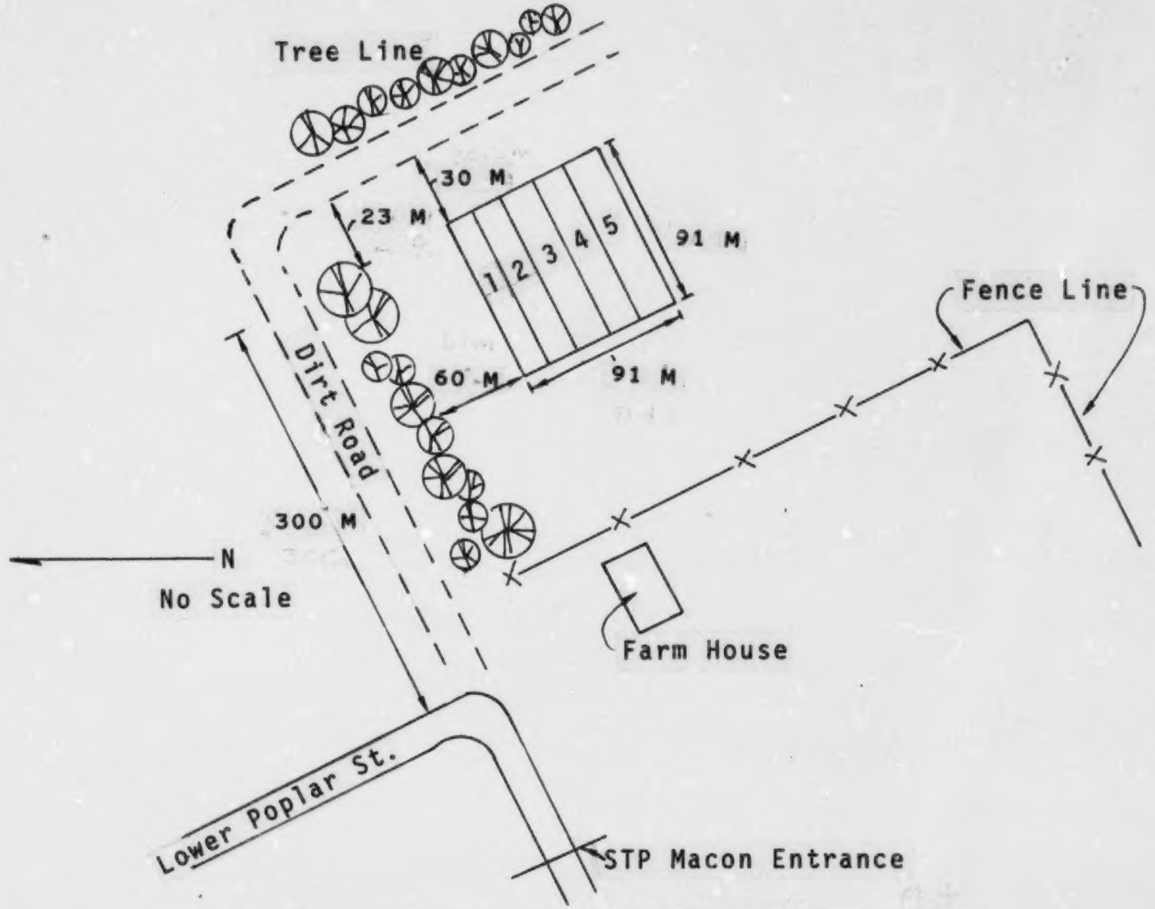

Tree Line
30 M
23 M
1
2
3
4
5
91 M
91 M
60 M
Fence Line
Dirt Road
300 M
N
No Scale
Farm House
Lower Poplar St.
STP Macon Entrance

Figure 2 Macon, Georgia Control Plot

in late May, is for the cheatgrass. Two additional cuttings are made of bermuda grass. In 1975, the total yield for both crops was approximately 3,000 bales.

The baled hay is used for beef cattle feeding. The present leasee reported no adverse effects to the cattle (one and one-half years feeding experience).

The treated field has never been tilled. The STP superintendent indicated that no pesticides, herbicides, or fertilizers have ever been used on this field.

The control plot had been planted to corn continuously from 1950 through 1970. In 1971, an oats-soybean rotation was initiated and presently continues. Typically, the field is harrowed in October, chisel-plowed, reharrowed and planted to oats. In February, a mixed grade of fertilizer (5-10-15) is applied at the rate of 670 kg/ha (600 lbs/acre). In early June, the oats are harvested. Yields were not available for any of the years. The farmer of the control field indicated that pesticides or herbicides had never been used.

CLIMATE

Located near the geographical center of Georgia, 322 km (200 miles) from the Atlantic Ocean, Macon is well situated to escape rigorous climatic extremes. Severe storms are infrequent. Tornadoes occur infrequently. Thunderstorms occur approximately two days out of five from June through August.

The average growing season is 246 days, and radical departures are uncommon. Snow occurs during most winters, but amounts are usually quite small as evidenced by only six

(17)

days with 2.5 cm (1 in) or more of snowfall in the 25-year period 1949 to 1973. Based on records dating from 1935, the average annual precipitation was 114 cm (44.7 in) with a high of 148 cm (58.2 in) in 1953, and a low of 66 cm (26.1 in) in 1954. Additional meteorological data are presented in Table 1.

SOIL DESCRIPTION

Regional Area

The soils of the Ocmulgee River flood plain, including the treated plot, are mapped by the Soil Conservation Service as the Chewacla-Wehadkee-Congaree Association. The soils range from well- to poorly-drained. In the past, the better drained areas have been farmed.

Overall, the soils of the Chewacla series make up about 40 percent of the soil association, soils of the Wehadkee series about 30 percent, and soils of the Congaree series 20 percent. Minor series comprise the balance. The somewhat poorly-drained Chewacla series has a dark brown silt loam surface layer, about 15 cm (6 in) thick, over pale brown to light yellowish-brown silty clay loam. Gray or light gray mottling occur within 51 cm (20 in) of the surface.

Soils of the Wehadkee series are poorly drained, have a dark brown surface over mottled dark gray, gray, strong brown, and reddish-brown silty clay loam. Soils of the Congaree series are well drained and have a dark brown silt loam surface layer, about 15 cm (6 in) thick, over dark reddish-brown silty loam to silty clay loam. The thickness of the sub-soil is approximately 160 cm (60 in).

TABLE 1

MACON, GEORGIA

Meteorological Data For The Current Year

Station: MACON, GEORGIA Standard time used: EASTERN Latitude 32° 42' N Longitude 83° 39' W Elevation (ground): 354 feet Year: 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity, pct.				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Averages			Extremes						Water equivalent			Snow, Ice pellets			Hour 01	Hour 07	Hour 13	Hour 19	Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F Maximum		Temperature °F Minimum		Elev. 362 feet m.s.l.
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	(Local time)				Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy					(b) 90° and above	32° and below	32° and below	0° and below	
JAN	62.7	39.7	51.2	80	29	23	14	424	3	6.09	2.37	12-13	0.0	0.0		77	85	62	68	28	0.8	7.7	26	W	25	66	6.2	8	9	14	12	0	3	9	0	0	7	0	1008.1
FEB	63.8	41.9	52.9	80	23	23	8	338	5	6.90	3.23	17	0.0	0.0		81	87	62	68	27	1.0	7.7	29	S	23	50	7.2	5	7	16	12	0	3	7	0	0	4	0	1005.4
MAR	67.5	43.7	55.6	84	23	25	3	306	25	6.66	2.34	13-14	0.0	0.0		73	82	56	59	26	2.0	9.7	29	NW	25	52	6.7	8	6	17	10	0	6	3	0	0	6	0	1004.1
APR	75.9	51.4	63.7	87	28	35	13	112	80	4.90	2.92	13-14	0.0	0.0		76	83	48	55	27	2.5	8.1	36	SE	30	57	6.4	8	6	16	11	0	8	4	0	0	0	0	1005.4
MAY	84.4	63.3	73.9	95	25	52	6	0	282	4.68	1.04	3	0.0	0.0		90	89	58	68	18	0.9	6.1	46	SW	16	51	7.3	4	9	18	13	0	13	4	7	0	0	0	1002.0
JUN	88.0	66.6	77.3	94	18	60	4	0	377	3.83	2.11	11-12	0.0	0.0		88	87	54	65	32	0.7	6.7	26	SW	10	65	5.9	6	15	9	12	0	12	2	8	0	0	0	1004.6
JUL	86.9	69.5	78.2	94	4	66	6	0	415	5.84	1.26	16	0.0	0.0		89	91	63	73	17	1.4	6.7	26	S	30	39	8.2	1	10	20	16	0	13	3	8	0	0	0	1004.1
AUG	90.5	69.7	80.1	98	26	66	30	0	476	2.17	0.66	31-1	0.0	0.0		92	94	59	69	18	0.6	5.7	27	NE	26	62	5.3	13	6	12	10	0	9	3	16	0	0	0	1006.1
SEP	83.2	63.0	73.1	96	4	48	27	10	261	4.71	1.99	20	0.0	0.0		92	94	61	76	06	1.3	6.6	32	SE	23	51	6.3	9	7	14	8	0	4	6	7	0	0	0	1005.1
OCT	78.5	54.7	66.6	87	14	40	21	57	113	3.53	1.67	7-8	0.0	0.0		88	89	55	73	02	2.1	6.2	28	S	17	67	4.7	16	3	12	6	0	0	1	0	0	0	0	1007.1
NOV	69.7	43.8	56.8	83	7	29	26	280	40	2.26	1.36	11-12	0.0	0.0		84	87	52	70	33	0.6	6.1	24	W	12	62	5.0	12	5	13	8	0	0	5	0	0	6	0	1008.8
DEC	59.7	35.1	47.4	75	15	15	19	537	0	3.91	1.12	30-31	0.0	0.0		82	84	55	68	31	2.0	7.0	39	W	31	52	5.3	12	6	13	10	0	0	4	0	0	14	0	1008.[illegible]
YEAR	75.9	53.5	64.7	98	AUG 26	15	DEC 19	2064	2077	55.48	3.23	FEB 17	0.0	0.0		84	88	57	68	29	0.6	7.0	46	SW	MAY 16	56	6.2	102	89	174	128	0	71	51	46	0	37	0	1005.8

TABLE 1 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches										
	Normal			Extremes						Water equivalent							Snow, Ice pellets			
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				11		11					27		27		27		27		27	
J	58.7	36.9	47.8	80	1975	3	1966	543	10	3.67	8.30	1964	0.69	1954	4.44	1962	3.7	1959	3.7	1955
F	61.8	39.0	50.4	80	1975	9	1973	423	15	4.38	9.12	1949	1.39	1968	3.23	1975	16.5	1973	16.5	1973
M	68.4	44.6	56.5	90	1974	22	1968	298	34	5.15	9.69	1962	1.26	1968	3.94	1970	T	1968	T	1968
A	78.3	53.2	65.8	94	1970	31	1971	66	90	3.55	8.42	1964	0.53	1972	3.65	1955	0.0		0.0	
M	86.0	60.9	73.5	99	1967	40	1971	6	249	3.57	11.77	1957	0.32	1956	4.01	1957	0.0		0.0	
J	90.9	68.2	79.6	100	1970	46	1972	0	438	3.86	9.06	1965	0.99	1954	4.97	1965	0.0		0.0	
J	92.1	70.7	81.4	104	1970	54	1967	0	508	4.52	9.04	1953	1.21	1952	2.89	1965	0.0		0.0	
A	91.8	70.0	80.9	104	1968	56	1969	0	493	3.65	7.09	1973	1.39	1968	2.96	1959	0.0		0.0	
S	86.6	64.9	75.8	99	1972	35	1967	0	324	3.10	8.82	1953	0.41	1970	4.80	1956	0.0		0.0	
O	78.2	53.2	65.7	94	1971	29	1965	82	103	2.31	9.39	1959	0.00	1963	5.35	1970	0.0		0.0	
N	67.9	42.4	55.2	85	1974	16	1970	304	10	2.39	5.89	1957	0.43	1956	1.63	1968	0.2	1950	0.2	1950
D	59.6	37.0	48.3	82	1972	15	1975	518	0	4.31	10.39	1972	0.58	1955	4.50	1972	0.5	1963	0.5	1963
YR	76.7	53.4	65.1	104	JUL 1970	3	JAN 1966	2240	2294	44.46	11.77	MAY 1957	0.00	OCT 1963	5.35	OCT 1970	16.5	FEB 1973	16.5	FEB 1973

Month	Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days											Average station pressure mb.
	Hour 01	Hour 07	Hour 13	Hour 19			Fastest mile					Sunrise to sunset							Temperatures °F				
	(Local time)				Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ½ mile or less	Max. (b) 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Elev. 362 feet m.s.l.
(a)	11	11	11	11	27	15	27	27		27	27	27	27	27	27	27	27	27	11	11	11	11	3
J	79	84	60	66	8.2	WNW	47	SW	1959	54	6.4	8	7	16	11	*	1	4	0	*	13	0	1008.0
F	75	82	54	59	9.1	WNW	60	NE	1960	57	6.1	8	7	13	10	*	2	3	0	0	12	0	1006.1
M	74	83	51	54	9.6	WNW	60	S	1954	62	6.1	9	8	14	11	0	3	2	*	0	5	0	1004.0
A	78	86	48	52	9.1	WNW	57	SE	1957	67	5.5	11	7	12	8	0	4	1	1	0	*	0	1005.1
M	83	87	51	58	7.8	NW	65	SE	1952	70	5.7	9	11	11	9	0	7	1	7	0	0	0	1002.0
J	86	87	54	63	7.4	NW	56	NW	1954	69	5.9	8	11	11	10	0	9	1	15	0	0	0	1003.5
J	88	89	59	69	7.0	SW	39	SW	1954	64	6.6	5	12	14	14	0	14	1	21	0	0	0	1004.1
A	89	91	59	70	6.4	NE	70	S	1961	70	5.7	9	12	10	11	0	10	2	19	0	0	0	1005.5
S	89	93	58	72	7.1	NE	40	NW	1956	64	5.8	8	10	12	8	0	3	2	11	0	0	0	1004.6
O	84	87	51	67	7.0	NE	32	NW	1954	69	4.5	15	6	10	6	0	1	2	1	0	1	0	1007.7
N	81	85	50	65	7.3	WNW	54	SW	1957	64	4.9	13	6	11	7	0	1	3	0	0	7	0	1008.1
D	80	83	56	67	7.9	NW	50	NW	1967	56	6.0	9	8	14	10	0	1	4	0	0	11	0	1007.3
YR	82	86	54	64	7.8	WNW	70	S	AUG 1961	63	5.8	112	105	148	112	*	57	26	75	*	49	0	1005.5

The Chewacla-Wehadkee association is strongly acid. It is low in natural fertility and medium in organic matter content. Permeability is moderate, while the water holding capacity is moderate to high. Tilth is generally good. The two soils occur on the flood plain in such intricate patterns that it has not been practical to map them separately. Typically, the profile for this association shows the A horizon ranging from silt loam, loam to sandy loam or fine sandy loam in texture, and from pale brown and brown to dark brown and reddish brown in color. The C horizons range from loam, silt loam to silty clay or loamy sand in texture. Color ranges from dark reddish brown and dark brown to brown and to dark yellowish brown. In many places, gray mottling is present in the C horizon below a depth of 76 cm (30 in).

The Congaree soil commonly occurs with the Chewacla soil. However, the Chewacla soil has poorer drainage than the Congaree soil. The Chewacla series also occupies a lower position on the landscape and is subject to more frequent flooding.

In the immediate area of the treated and control plots, the soil association is dominated by soils of the Congaree series.

Treated Plot

The soil profile of the treated plot basically followed the above descriptions. The surface soil ranged in depth from 8 to 15 cm (3 to 6 in) and was a dark brown silty loam.

Below the 15 cm (6 in) depth and extending to approximately 86 cm (34 in) was a layer of silty loam ranging from brown to dark brown. Sand followed at depths from 86 cm (34 in) to greater than 117 cm (46 in). Below the sand was a layer of moist red clay to an undetermined depth.

The soil types appeared quite uniform over the sample plot, although the thickness of the soil layers varied as described above. The moisture content of the clay layer varied with location, being highest (essentially saturated) at the edge of the sample plot adjacent to the lake.

Sample points x and y in quadrants 2 and 3 (Figure 1) were the only two areas in which the bottom layer of clay was not reached. These two locations were uniformly sandy to depths of 122 cm (48 in).

Control Plot

The reddish brown silty loam surface soil of the control plot varied in depth from 20 to 30 cm (8 to 12 in). It was underlain with a layer of silty sand, which presumably was a result of mixing of the underlying layer of sand with the surface silty loam during cultivation. Below the sand (extending to a depth of approximately 91 cm (36 in)) was a thin clay lens ranging in thickness from 0 to 15 cm (0 to 6 in). Following was a layer of paleosol (buried topsoil) of undetermined depth. This soil profile was relatively uniform throughout the control plot. Texture, pH and other related soil data are shown in Table 2.

TABLE 2

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

MACON, GEORGIA

PLOT DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N (2)	PH (1)	CEC
			SAND	SILT	CLAY					
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	43.2	31.6	70	29	1	1.41	27.0	36.2	3.6	17
20-46 CM	16.0	0.79	83	13	4	0.053	11.2	27.0	4.4	10
46-61 CM	8.4	0.59	90	7	3	0.024	0.15	10.8	4.6	7
61-91 CM	6.3	0.33	97	1	2	0.011	3.05	6.31	4.9	4
91-122 CM	21.6	1.30	35	50	15	0.052	6.46	2.89	4.4	9
CONTROL										
SURFACE	13.2	1.30	65	28	7	0.079	4.15	26.2	4.1	15
20-46 CM	11.0	0.31	70	18	12	0.034	3.92	24.4	4.2	11
46-61 CM	9.8	0.22	85	6	9	0.015	2.93	4.86	4.6	6
61-91 CM	9.0	1.53	83	5	12	0.013	3.29	7.06	4.5	4
91-122 CM	24.7	1.24	29	48	23	0.053	4.63	11.0	5.5	8

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

Approximately 90 percent of the population of Bibb County (143,000 - 1975) was located within the Macon city limits. This population was served by two wastewater treatment facilities - the Lower Poplar Street Plant (the plant under study), and the Rocky Creek Plant. The former, constructed in 1959, serves approximately three-quarters of the population. As originally constructed, the plant provided grit removal and primary settling with discharge of primary effluent to the Ocmulgee River. Sludge from the primaries was stabilized in one of three anaerobic digesters, providing a combined three-month detention time. From the digesters, the sludge was discharged to drying beds. Until 1965, the dried sludge was removed from the beds by STP personnel and hauled free of charge to local farmers.

In 1963, the STP was upgraded to secondary treatment with the construction of two high-rate trickling filters, a secondary clarifier, and two additional anaerobic sludge digesters. The trickling filters, in parallel, are 51.8 m (170 ft) in diameter and capable of handling up to 56,800 cu m/day (15 mgd) each.

In 1965, the STP commenced spreading of liquid digested sludge on 50.6 ha (125 acres) of adjacent city-owned property. Essentially the entire area has at one time or another been treated with sludge. The sludge is typically spread four times annually between the months of April and November.

Sludge is usually not spread during the winter months since plant growth is at a minimum and the soil moisture is at or near saturation. Spreading, however, has varied over the years depending on weather conditions. Combined capacity of the two secondary sludge digesters affords sufficient storage volume during the non-spreading months.

The STP was designed for an average loading of 45,400 cu m/day (12 mgd). It currently serves an estimated 107,000 residents with a population equivalent of 125,000. The STP superintendent stated that a significant but undetermined percentage of infiltration occurs. Additionally, storm water is routed through the STP. A record peak daily flow reading of 93,500 cu m/day (24.7 mgd) was recorded in May, 1975. Influent, effluent, and treatment efficiencies are shown in Table 3.

An estimated 30 percent of the influent to the STP is industrially derived. The principal contributors are:

Company	Type of Manufacturing
Proctor and Gamble	Edible oils
Cagle's	Poultry processors
G. Burns Company	Fertilizer from tannery wastes
Tex-Print	Textile dyeing
Y.K.K. Zipper	Zipper manufacturing, dyeing

Individual industry effluents have not been monitored. Of the industries listed, only the poultry processor discharges a waste thought to have a significantly higher BOD than normal domestic sewage. Proctor and Gamble provides pretreatment of their wastewater prior to discharge. The wastewaters from Tex-Print and Y.K.K. Zipper, although of relatively high volume, contain only small amounts of dyes and are thought not to contribute

TABLE 3

MACON, GEORGIA SECONDARY EFFLUENT TREATMENT EFFICIENCIES

Month	Yr.	Average Daily Flow cu m/day	Influent		Effluent		% Reduction	
			BOD (mg/1)	SS (mg/1)	BOD (mg/1)	SS (mg/1)	BOD	SS
Apr.	75	60220	144	91	36	75	75.0	17.6
May	75	57040	235	129	47	80	80.0	38.0
June	75	49510	192	127	43	77	78.6	39.4
Aug.	75	48110	165	117	47	71	71.5	31.3
Sept.	75	36750	213	109	69	67	67.6	38.5
Oct.	75	38570	186	125	56	69	69.9	44.8
Nov.	75	38380	235	155	91	61	61.3	60.6
Dec.	75	39290	255	-	86	66	66.3	-
Jan.	76	47620	164	145	69	57	57.9	60.7
Feb.	76	39550	276	268	122	55	55.8	79.5
Mar.	76	53670	244	166	111	54	54.5	67.5
Avg.		42390	209.9	143.2	70.6	66.5	67.1	47.8

substantial BOD loading. Seasonal fluctuations are not significant.

At present, the industries pay a water use charge; no charges based on wastewater discharge have been initiated.

Sludge Stabilization and Storage

Sludge stabilization is anaerobic and in two stages. Sludge from the secondary clarifiers is returned to the primaries, from which combined settled sludge is pumped to two 6,740 cu m (1.78 mg) capacity primary digesters. Detention time is approximately 30 days each. First step sludge is then pumped to one of three 3,180 cu m (6.84 mg) capacity secondary digesters. Combined detention time for the secondaries is approximately three months. Supernatent is returned to the primary clarifier influent. No chemicals are added at the STP.

Sludge from the secondary and primary digesters is removed for either landspreading or bed drying. Distribution was estimated by STP personnel to be approximately 90 percent landspreading and 10 percent bed drying.

Each of the 24 drying beds measures 60 x 9.8 x 0.8 m (197 x 32 x 2.5 ft) and provides sufficient capacity for an additional 190 to 265 cu m (50 to 70,000 gal) of sludge.

The bed-dried sludge has historically been landfilled, but recently (1976) it has been used by the city of Macon as a soil conditioner and supplement to planter boxes as part of a city beautification program.

Historical analytical data (see Table 4) on sludge is represented by the Phase I stabilized sludge sample obtained on

TABLE 4

MACON, GEORGIA - STABILIZED LIQUID SLUDGE ANALYSIS[1]

Parameter	Concentration[2]
	-µg/g -
Cd	5.93
Cu	11.90
Ni	47
Zn	1050
Pb	283
Moisture (%)	89.2

[1] Phase I stabilized sludge sample, October 9, 1974.

[2] Data expressed on an oven dry weight basis.

October 9, 1974. No other chemical data on sludge exists.

Disposal of Sewage Sludge

From 1974-75 data, it is estimated that the STP generates an average of 7,219 cu m (1.97 mg) of sludge annually, equivalent to 849 dry m tons/yr (935 dry tons/yr) assuming an average sludge solids of 11.4 percent (averaged analytical data). Sludge distribution data for the years 1972 to 1975 are presented in Table 5.

The quantity spread has varied from month to month over the years, but four years of recorded (1972-1975) spreading have resulted in 29,900 cu m (7.9 mg) of sludge being distributed over the STP property. Assuming an average of 11.4 percent sludge solids, this is equivalent to 3,403 dry m tons (3,750 dry tons).

The sludge is spread using a 5.2 cu m (1,376 gal) tank truck. The tank is a refitted pressure filter tank from a water treatment plant, modified for sludge spreading by the addition of two control valves. Originally, the tank was mounted on a trailer and towed by a truck. However, the excessive weight of the tank assembly caused repeated failure of the towing hitch.

Two valves on the rear of the tank control the rate of sludge discharge onto a triangular-shaped splash pan. The pan design spreads the sludge over an area approximately 3 m (10 ft) wide as the truck is driven across the field. Each load is normally emptied over a distance of approximately 274 m (900 linear ft).

TABLE 5

MACON, GEORGIA - LIQUID SLUDGE HAULING (cu m)

Month	Year			
	1972	1973	1974	1975
Jan.	5,375	0	0	405
Feb.	0	0	0	0
Mar.	4,010	254	364	0
Apr.	950	0	125	625
May	351	195	805	632
June	0	113	135	226
July	452	0	5,442	0
Aug.	1,808	0	60	0
Sept.	120	0	426	68
Oct.	0	0	1,003	182
Nov.	1,298	0	0	3,233
Dec.	541	0	436	271
Total	14,905	562	8,796	5,642

Interviews with the STP personnel and neighbors adjacent to the STP indicated no apparent aesthetic, odor or other environmental problems associated with the disposal operations. The sludge spreading has contributed to a lush grass cover on the 50.6 ha (125 acre) site.

Photographs 1 through 6 show, respectively, a view of the treated field, soil and grass on treated plot, the control field, plants grown on the control plot, drying beds at the STP, and the tank truck used for spreading.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

The Director of Public Works, the Health Department, and the local newspaper were contacted to determine public attitudes toward landspreading of sludge. A Bibb County Health Department representative stated that verbal approval had been given for sludge spreading when it began back in 1965. They continue to believe that sludge spreading is a desirable and acceptable method of sludge disposal.

When questioned in a similar manner, the Director of Public Works Department stated that this method of sludge disposal had never been questioned or challenged.

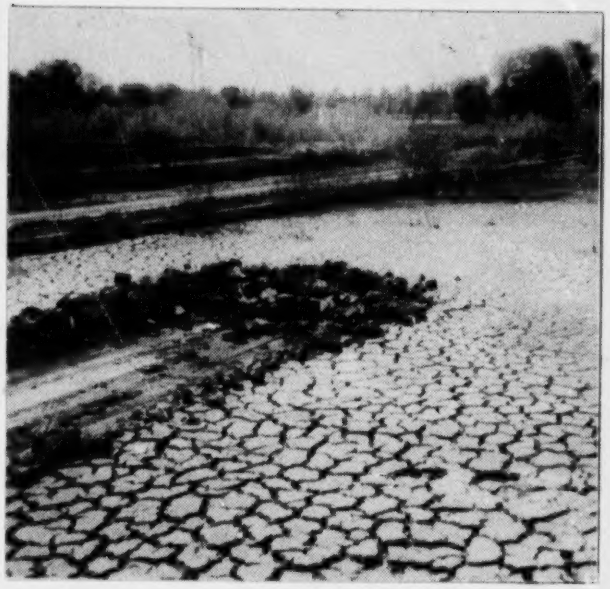
A telephone interview with the historian at the local newspaper indicated that there had never been articles in the paper pertaining to sludge disposal. The general public appears to be unconcerned and/or uninformed with regard to sludge disposal practices in the Macon area.

Photograph 1
Treated Site

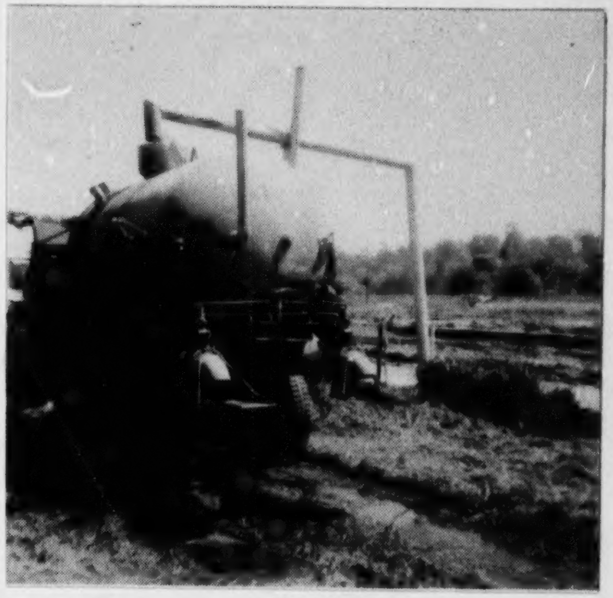
Photograph 2
Treated Site Plants

Photograph 3
Control Site

Photograph 4
Control Site Plants



Photograph 5
S.T.P. Drying Beds



Photograph 6
S.T.P. Tank Truck

Interviews with local Soil Conservation Service and USDA personnel indicated their awareness and acceptance of the sludge spreading practices.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

In May, 1975, the Solid Waste Management Section, Environmental Protection Division of the Georgia Department of Natural Resources issued "Guidelines for the Sanitary Landfill or Landfill Disposal of Liquid, Semi-Solid and Industrial Sludge Wastes." The guidelines govern the disposal of municipal and industrial sludges at approved locations within public or privately operated disposal sites, or at disposal sites designed and operated solely for the disposal of these wastes. Limitations for sludge spreading on farm land are not included. Currently, there are neither guidelines nor legislation governing the sludge spreading program in Macon.

All STP employees receive influenza, tetanus, and typhoid innoculations on a voluntary basis free of charge.

ECONOMICS

Equipment Description and Cost

Total capital investment for the sludge spreading system was approximately $5,000. In March, 1966, the plant purchased a 3.8 cu m (5 cu yd) dump truck for $4,765. The sludge tank was obtained at no cost from a water treatment plant and mounted on the truck. Approximately $80 was spent to install two salvaged plug-valves on the tank.

To facilitate loading, approximately $200 was spent to install a remote control electrical switch to operate the sludge pumps at the digesters. The sludge tank is filled from a pipeline adjacent to the drying beds.

As mentioned previously, all of the sludge is not spread on the STP site. Therefore, other costs are incurred. For example, a backhoe is used to periodically remove sludge from the drying beds. A backhoe was originally purchased in 1960 for $8,600 and traded in 1974 on the purchase of a new $25,000 JD 500 backhoe. A credit for $5,600 was allowed for the old backhoe. The backhoe is used an estimated 75 percent of the time for handling the bed-dried sludge.

Detailed costs for operation and maintenance (O&M) of the sludge spreading equipment for the four-year period beginning October, 1971, are shown in Table 6.

Table 7 provides a cost analysis for the spreading operation. A sludge solids content of 11.4 percent was used for calculating total sludge quantity on a dry weight basis. Both the liquid and bed-dried sludge were included in the analysis.

SAMPLING AND ANALYSIS

Sludge

On April 5 and 6, and October 20, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and one of the secondary sludge digesters.

Soil

On April 5 and 6, 1976, surface and subsurface soil samples were obtained from both the treated and control plots.

TABLE 6

MACON, GEORGIA - OPERATION AND MAINTENANCE COSTS FOR SLUDGE SPREADING

Year*	Fuel ($)		Repairs ($)				
	Gasoline	Oil	Parts	Labor	Tires	Misc.($)	Total($)
1971-72	156	7	79	46	91	0	379
1972-73	148	7	82	103	0	4	344
1973-74	232	6	331	285	0	0	854
1974-75	267	4	311	218	703	5	1,508
Total							$3,085
Average Annual Cost							$ 771

*October 1 through September 30.

TABLE 7

COST FOR DISPOSAL OF SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation[1]			
1966 Dump Truck	$4,765		
1974 Backhoe	$19,400[2]		
Total Annual Capital Cost			$2,118
Annual Operating Cost			
Personnel	Hourly Rate	% Time Worked	Cost
1 Operator - Liquid	$2.40	19	$ 924
1 Operator - Beds	2.40	10.2	$ 491
			$1,415
Fringe Benefits (25 percent)			$ 354
Vehicle Operation and Maintenance			$ 771
Total Annual Operating Cost			$2,540
Total Annual Capital and Operating Cost			$4,658
Contingency Factor[3]			$ 466
Total Cost			$5,124

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$5{,}124}{708 \text{ dry tons}} = \begin{array}{c}\$7.98/\text{dry m ton} \\ (\$7.24/\text{dry ton})\end{array}$$

---

[1] Vehicles were fully depreciated over 8 years assuming 8 percent interest equivalent to $169.68 per $1,000 annually.

[2] The JD 500 Backhoe was fully depreciated over 10 years at 8 percent interest, equivalent to $145.56 per $1,000 annually.

[3] A 10 percent contingency factor is added to cover such items as administrative overhead.

As shown in Figures 1 and 2, both plots were divided into five sections. Approximately 40 surface 0 to 20 cm (0 to 8 in) soil samples were collected from each of the sections. Dead plant materials on the top portion and sand in the lower portion of each core were discarded prior to the core being placed in a sample bag.

Subsurface soil samples were obtained with a 7.6 cm (3 in) stainless steel bucket auger. At the treated plot, the top 20 cm (8 in) of soil were discarded from the bucket auger. Samples obtained from the depths between 20 and 46 cm (8 and 18 in) were labeled Horizon A; 46 to 61 cm (18 to 24 in) - Horizon B; 61 to 91 cm (24 to 36 in) - Horizon C; and 91 to 122 cm (36 to 48 in) - Horizon D.

Both surface and subsurface soil samples at the control plot were obtained in exactly the same manner as those at the treated plot. Since the surface soil layer at the control plot was approximately 20.3 to 30.5 cm (8 to 12 in) deep, approximately 25 surface soil cores were obtained from each section.

Plants

Grass samples were obtained by shearing the plants approximately 7.6 to 12.7 cm (3 to 5 in) from the ground. Each sample contained approximately 50 to 100 individual blades ranging in length from 15.2 to 45.7 cm (6 to 18 in). Approximately 20 such samples were obtained from each section. Plant samples from both plots were taken in the same manner.

Tables 8 through 14 present the following:

Table	Description
8	Chemical Characterization of Stabilized Sludges
9	Concentration of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
10	Total Metal Concentrations in Individual Subsurface Soil Samples
11	Metal Concentrations in Surface Soils and Plants
12	Selenium in Composite Plants and Soils
13	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
14	Parasites in Sludges, Soils, and Plants
15	Concentration of Microbes in Sludges, Soils, and Plants

Figures 3 to 12 present particle size analyses of the various soil composites.

TABLE 8

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM MACON, GEORGIA

	(4/5/76)	(10/20/76)	Average
Volatile Solids (%)	33.75	39.96	36.9
NO_3 - N	14.6	<1.07	7.8
NH_4 - N	5305	16600	10952
Organic N	23872	45196	34534
P	7203	17393	12298
K	1619	2786	2203
Na	1492	6268	3880
Ca	14915	40732	27823
Mg	10500	13679	12090
SO_4	267	429	348
Cl	593	1464	1029
Ag	1.02	2.14	1.58
As	2.80	1.61	2.21
B	37.0	107	72
Cd	10	13.8	11.9
Cr	1148	1113	1131
Co	24.6	17.9	21.3
Cu	660	1250	955
Fe	24873	22250	23562
Hg	9.41	23.4	16.4
Mn	452	750	601
Mo	8.73	20.2	14.5
Ni	103	171	137
Pb	31737	911	16324
Se	4.07	23.4	13.7
Zn	1228	2304	1766
H_2O (%)	88.2	87.7	88
pH	7.4	7.8	

All Units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 9

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

MACON, GEORGIA

PLOT/ DEPTH:	TOTAL METALS (2)					DTPA EXTRACTABLES			
	CD	CU	NI	ZN	PB	CD	CU	NI	ZN
	μG/G					μG/G			
TREATED									
SURFACE	5.89	267	67.6	475	325	1.42	64.30	13.70	269.
20-46 CM.	0.96	13.3	17.1	80.4	35.4	0.22	4.10	2.55	37.80
46-61 CM.	0.47	10.1	9.44	39.0	19.4	0.10	1.63	0.94	16.40
61-91 CM.	0.33	6.93	12.5	27.5	13.9	0.06	1.20	0.66	9.59
91-122 CM.	0.99	19.6	24.4	88.5	49.6	0.10	2.40	1.70	27.60
CONTROL									
SURFACE	0.76	11.9	19.1	27.7	35.0	0.08	1.23	0.72	1.14
20-46 CM.	0.63	10.5	13.6	25.1	28.5	0.03	0.74	0.40	0.87
46-61 CM.	0.51	6.00	12.3	15.5	16.8	0.04	0.62	0.27	0.59
61-91 CM.	0.40	6.56	13.4	15.3	13.1	0.06	0.72	0.29	1.03
91-122 CM.	0.95	20.4	24.0	52.4	38.9	0.08	3.31	0.55	1.02

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO_3-$HCLO_4$ DIGESTION.

TABLE 10

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES(1)

MACON, GEORGIA

SECTION/ DEPTH	TREATED CD	TREATED CU	TREATED NI	TREATED ZN	CONTROL CD	CONTROL CU	CONTROL NI	CONTROL ZN
	μG/G				μG/G			
SECTION 1								
20-46 CM.	0.67	14.7	12.1	79.1	0.65	10.8	13.7	30.1
46-61 CM.	0.44	6.90	6.94	28.3	0.38	5.69	10.6	21.6
61-91 CM.	0.39	5.00	5.46	28.5	0.44	9.13	14.9	28.6
91-122 CM.	1.08	22.0	25.3	97.0	1.00	19.3	23.7	57.4
SECTION 2								
20-46 CM.	0.67	11.2	12.2	69.6	0.65	9.12	13.4	26.1
46-61 CM.	0.50	7.24	10.3	31.0	0.54	8.23	13.1	26.7
61-91 CM.	0.29	4.65	5.31	27.1	0.33	5.31	8.18	11.5
91-122 CM.	1.00	19.1	25.9	133.	0.87	19.8	22.7	56.8
SECTION 3								
20-46 CM.	1.27	26.1	26.1	156.	0.39	7.17	8.92	16.1
46-61 CM.	0.22	3.80	5.28	18.3	0.32	4.47	9.26	15.1
61-91 CM.	0.19	3.62	5.46	19.0	0.40	6.39	11.6	21.0
91-122 CM.	0.88	21.4	26.0	91.4	0.99	22.0	26.6	62.2
SECTION 4								
20-46 CM.	1.04	11.7	19.8	87.5	0.42	7.75	10.4	18.1
46-61 CM.	0.35	4.84	6.83	22.5	0.23	2.47	5.30	8.50
61-91 CM.	0.33	7.36	7.13	26.5	0.32	3.93	6.98	11.0
91-122 CM.	0.85	16.70	22.1	69.9	1.07	20.9	26.3	56.6
SECTION 5								
20-46 CM.	0.64	10.7	12.3	85.2	0.80	14.3	16.9	40.2
46-61 CM.	0.55	7.18	7.93	46.1	0.44	6.21	9.74	18.4
61-91 CM.	0.37	8.54	7.90	39.0	0.59	3.79	5.77	10.5
91-122 CM.	0.97	21.1	24.1	62.8	0.87	23.1	27.6	55.9

(1) HNO_3-$HClO_4$ DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 11

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS (1)

MACON, GEORGIA

SAMPLE	SURFACE SOIL CD	CU	NI	ZN	PB (2)	PLANT CD	CU	NI	ZN	PB (2)	ORG-N (2)
	μG/G					μG/G					
TREATED											
COMPOSITE	5.89	267	67.6	475	325	0.77	18.5	16.4	375	4.86	3.54
SECTION 1	5.49	272	86.9	559		0.84	30.0	17.0	455		
SECTION 2	5.57	294	67.6	574		0.77	19.8	16.7	404		
SECTION 3	4.99	323	65.2	552		0.58	24.1	15.1	392		
SECTION 4	4.92	293	66.9	538		0.73	17.2	21.6	325		
SECTION 5	3.92	233	57.6	456		0.62	18.8	16.6	341		
MEAN	4.98	283	68.8	536		0.71	22.0	17.4	383		
STD. DEV.	0.66	33.3	10.9	46.5		0.11	5.16	2.46	52		
CONTROL											
COMPOSITE	0.76	11.9	19.1	27.7	35.0	0.31	5.93	3.90	30.8	4.38	2.80
SECTION 1	0.82	16.1	23.1	39.8		0.36	6.02	3.50	31.5		
SECTION 2	0.61	10.5	17.0	37.6		0.22	5.69	3.28	28.0		
SECTION 3	0.39	9.38	13.4	22.1		0.31	6.34	3.83	33.3		
SECTION 4	0.40	10.2	20.9	24.2		0.39	5.31	3.70	31.3		
SECTION 5	0.52	14.2	19.2	34.6		0.29	4.70	3.83	31.9		
MEAN	0.55	12.08	18.72	31.66		0.31	5.61	3.63	31.2		
STD. DEV.	0.18	2.91	3.72	8.02		0.07	0.64	0.24	1.95		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

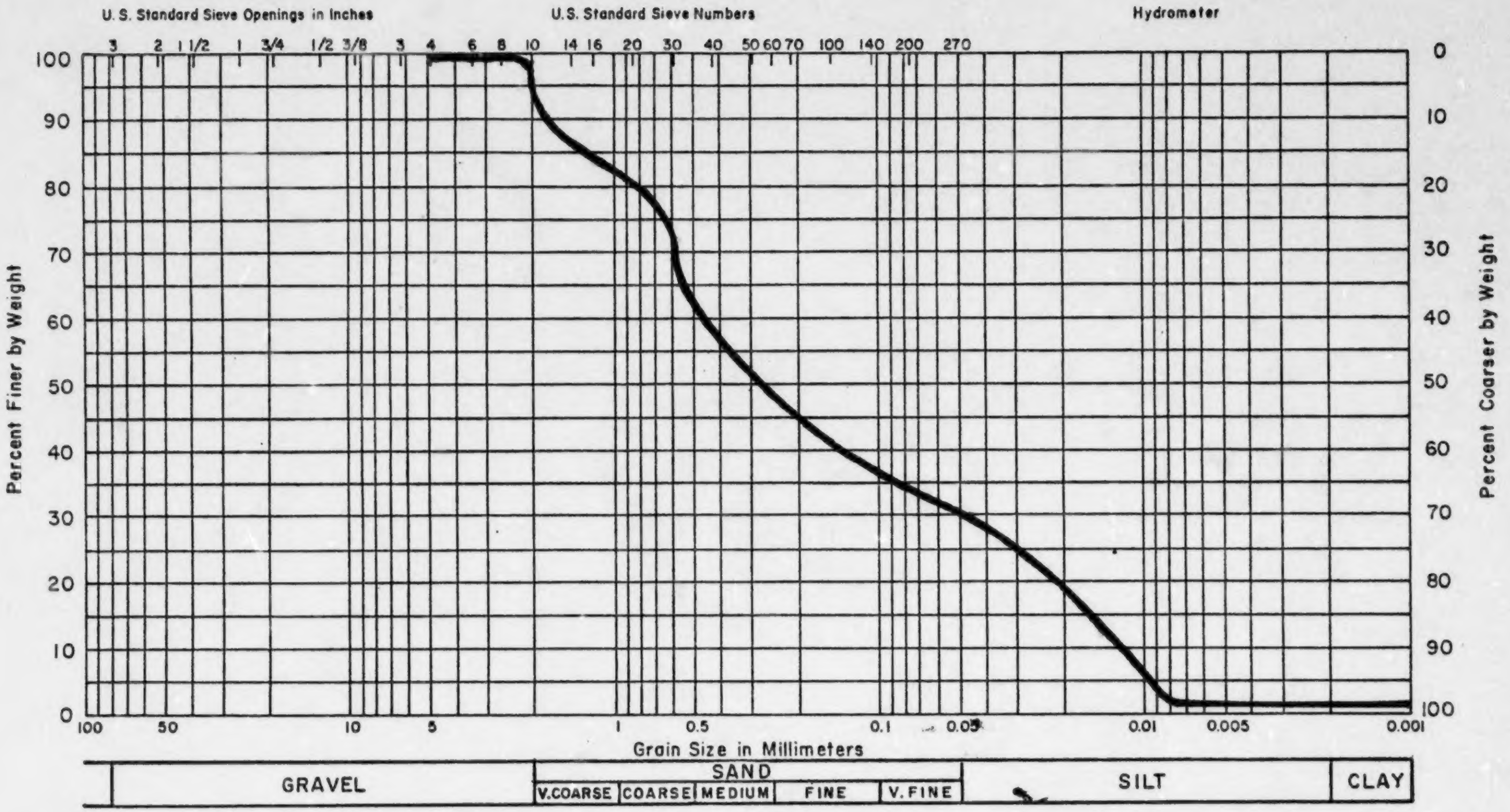
(2) ANALYSIS ON COMPOSITE ONLY.

TABLE 12

SELENIUM IN COMPOSITE PLANTS AND SOILS

MACON, GEORGIA

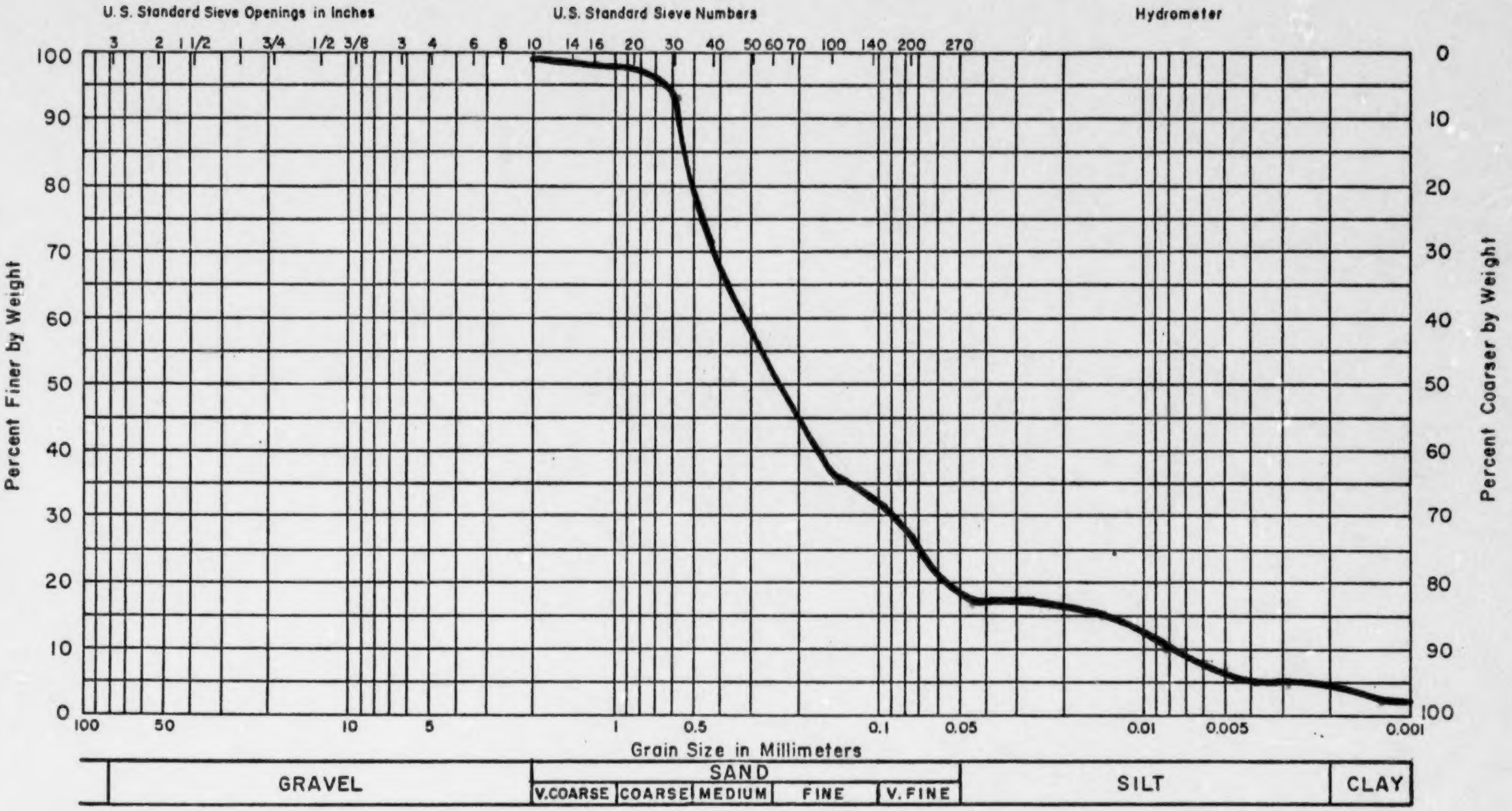
	Treated Plot	Control Plot
	. . . . µg/g	
Plant (Cheatgrass)	<0.02	<0.02
Soil (depth in cm)		
0-20	0.26	<0.02
20-46	0.40	<0.02
46-61	0.26	<0.02
61-91	1.20	<0.02
91-122	0.56	<0.02



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
472	Macon	70	29	1	Sandy Loam/Loamy Sand
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

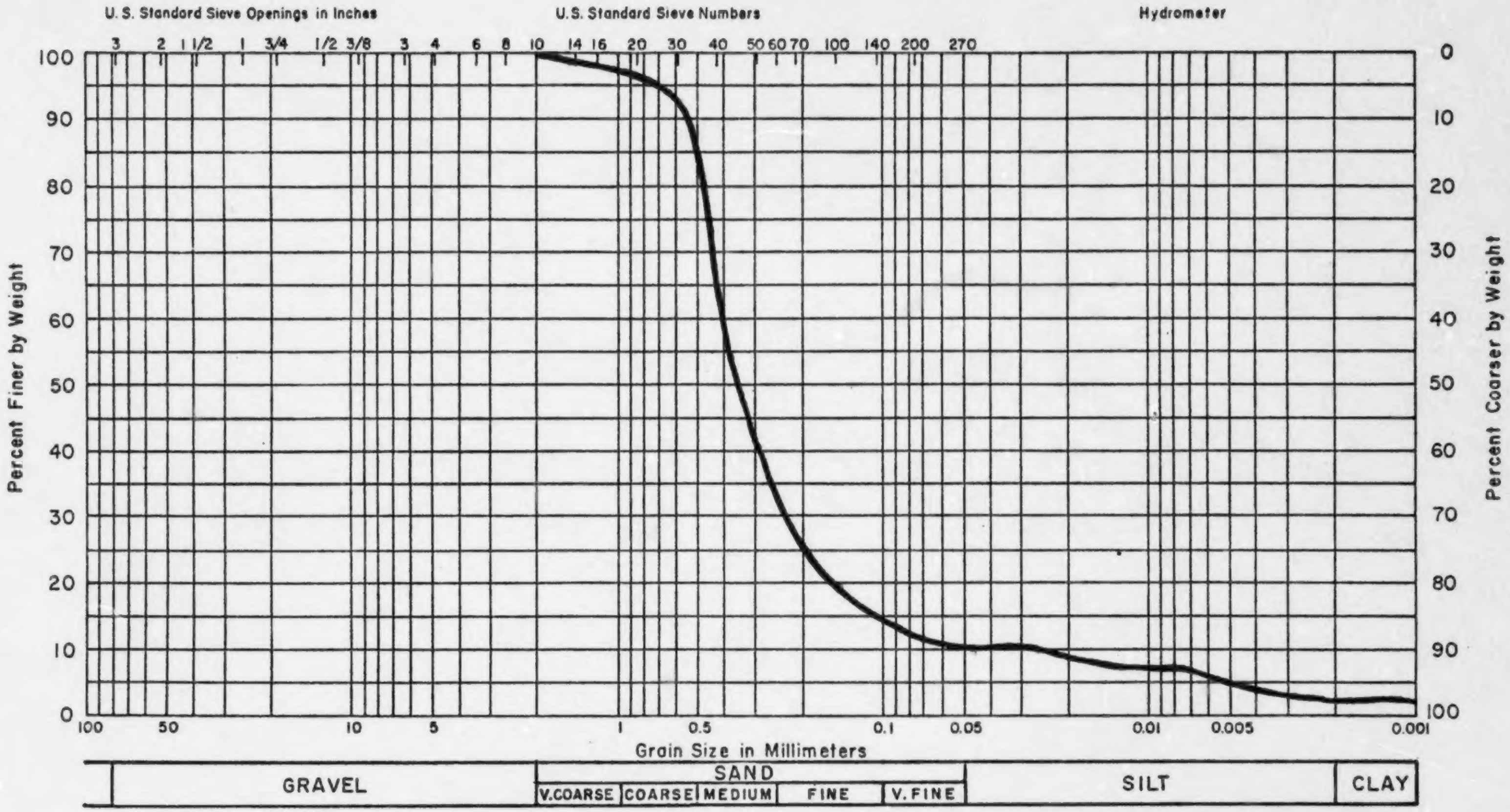
Figure 3 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
488	Macon	83	13	4	Loamy Sand
	Treated				
	20-46 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

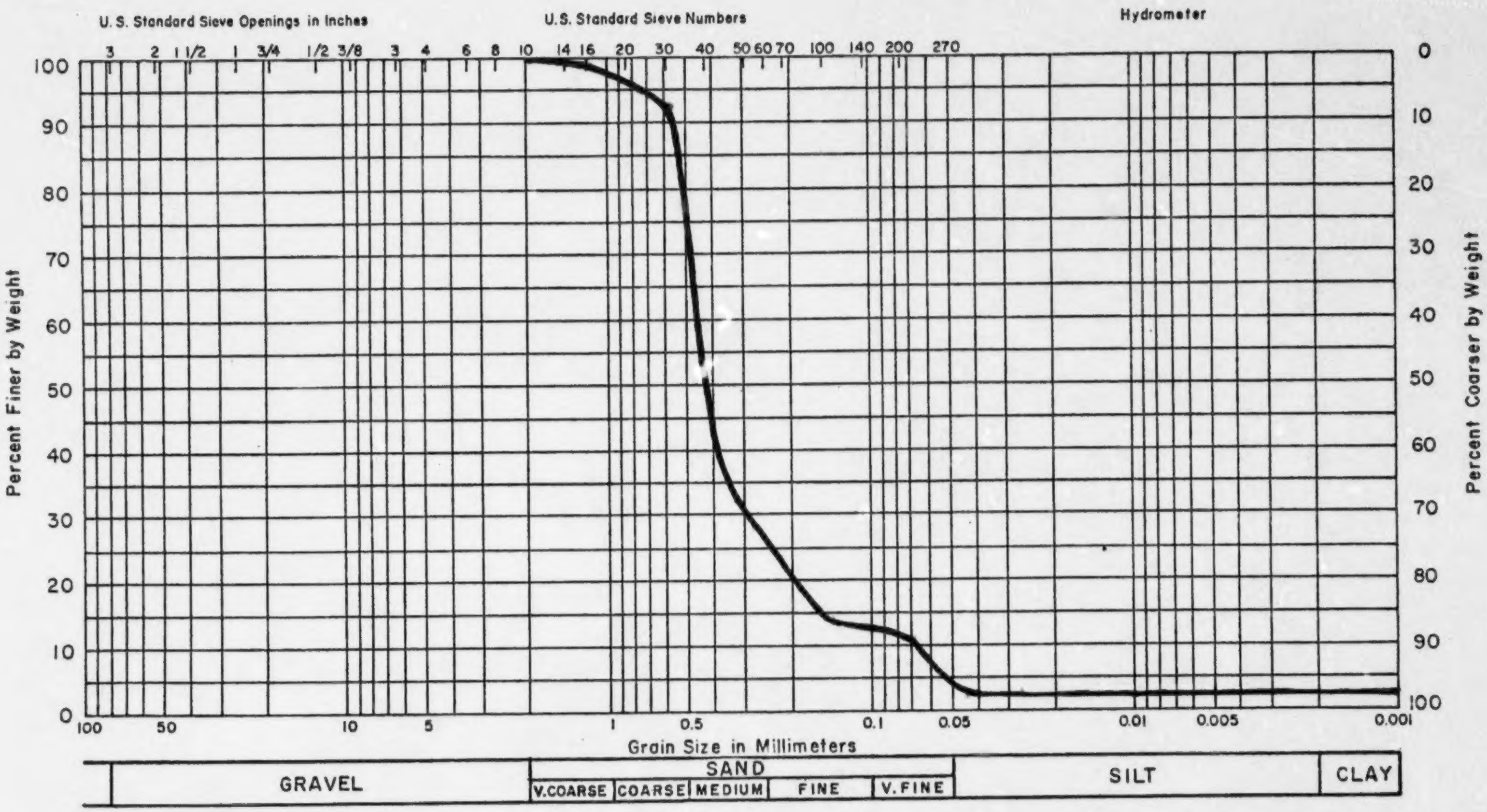
Figure 4 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
504	Macon	90	7	3	Sand
	Treated				
	46-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

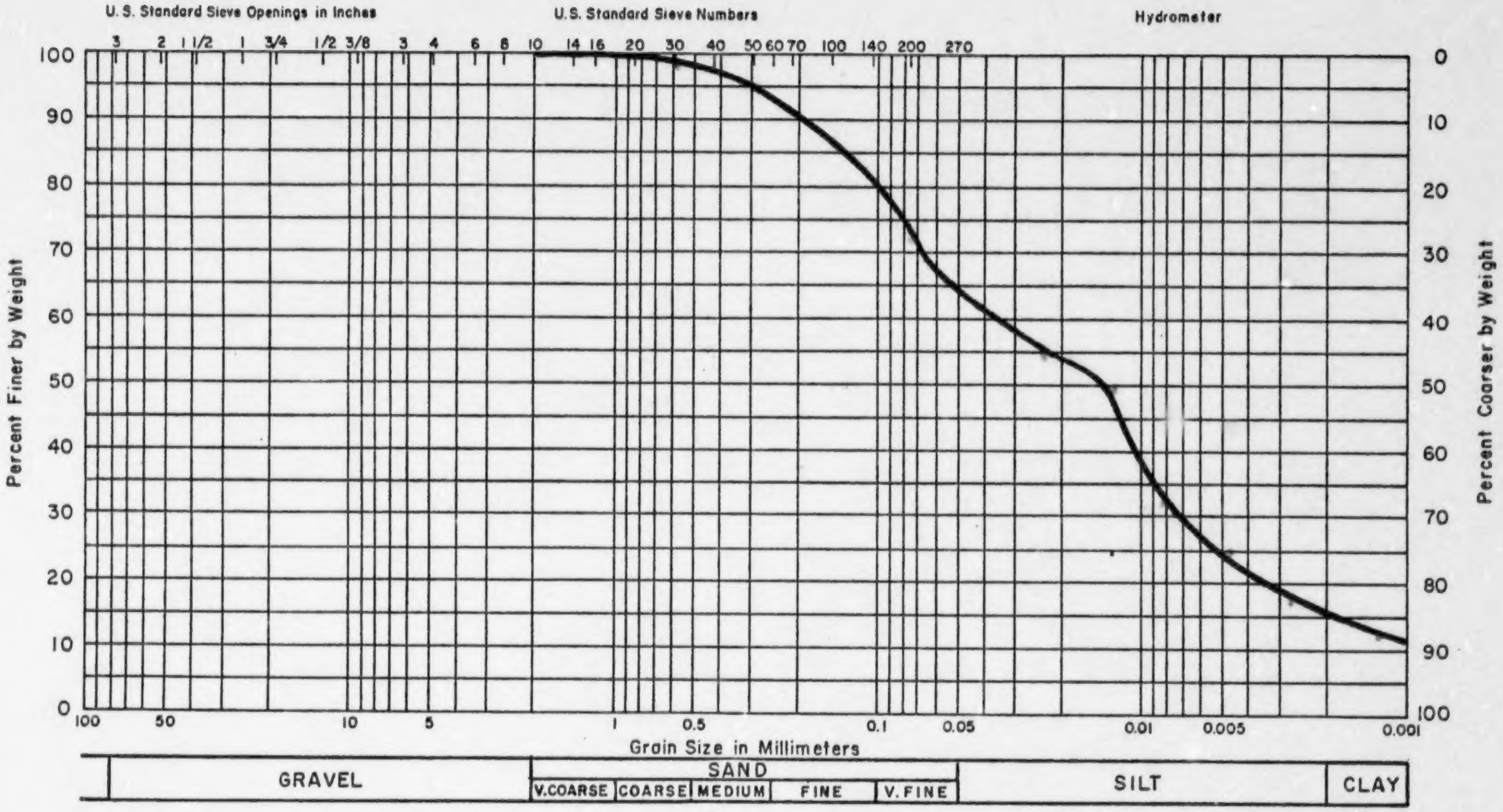
Figure 5 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
520	Macon	97	1	2	Sand
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

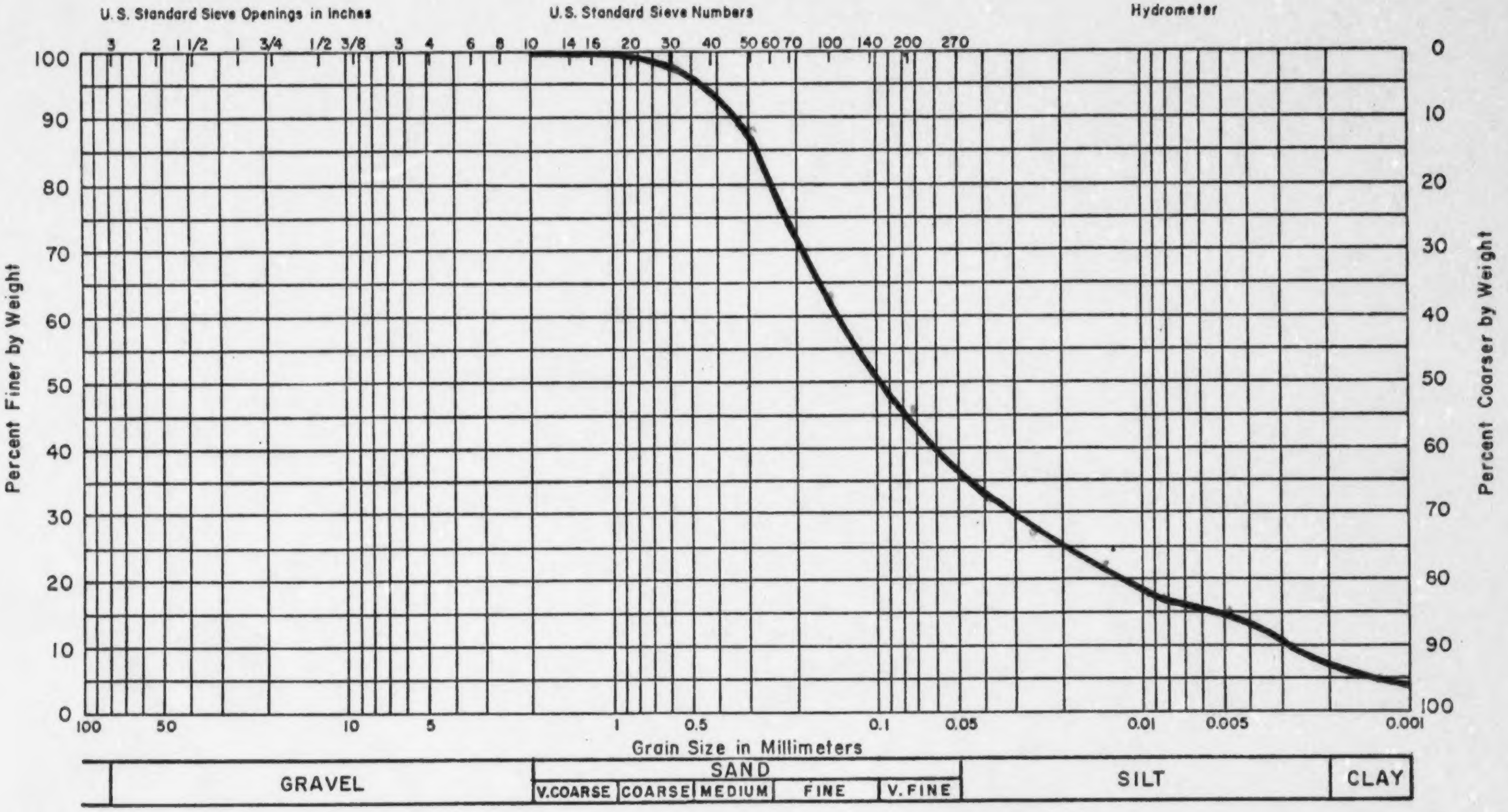
Figure 6 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
536	Macon	35	50	15	Silt Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

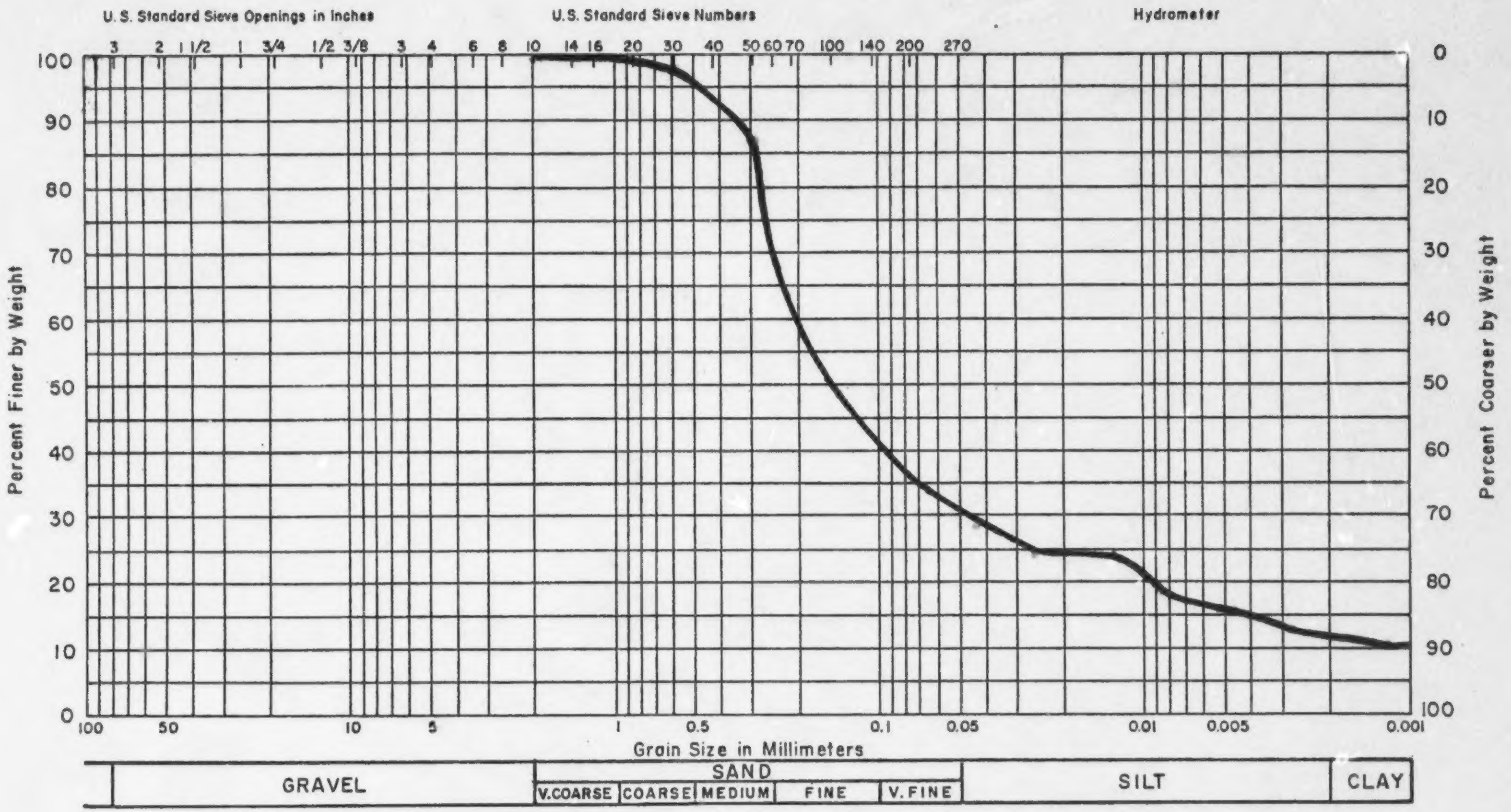
Figure 7 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
480	Macon	65	28	7	Sandy Loam
	Control				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

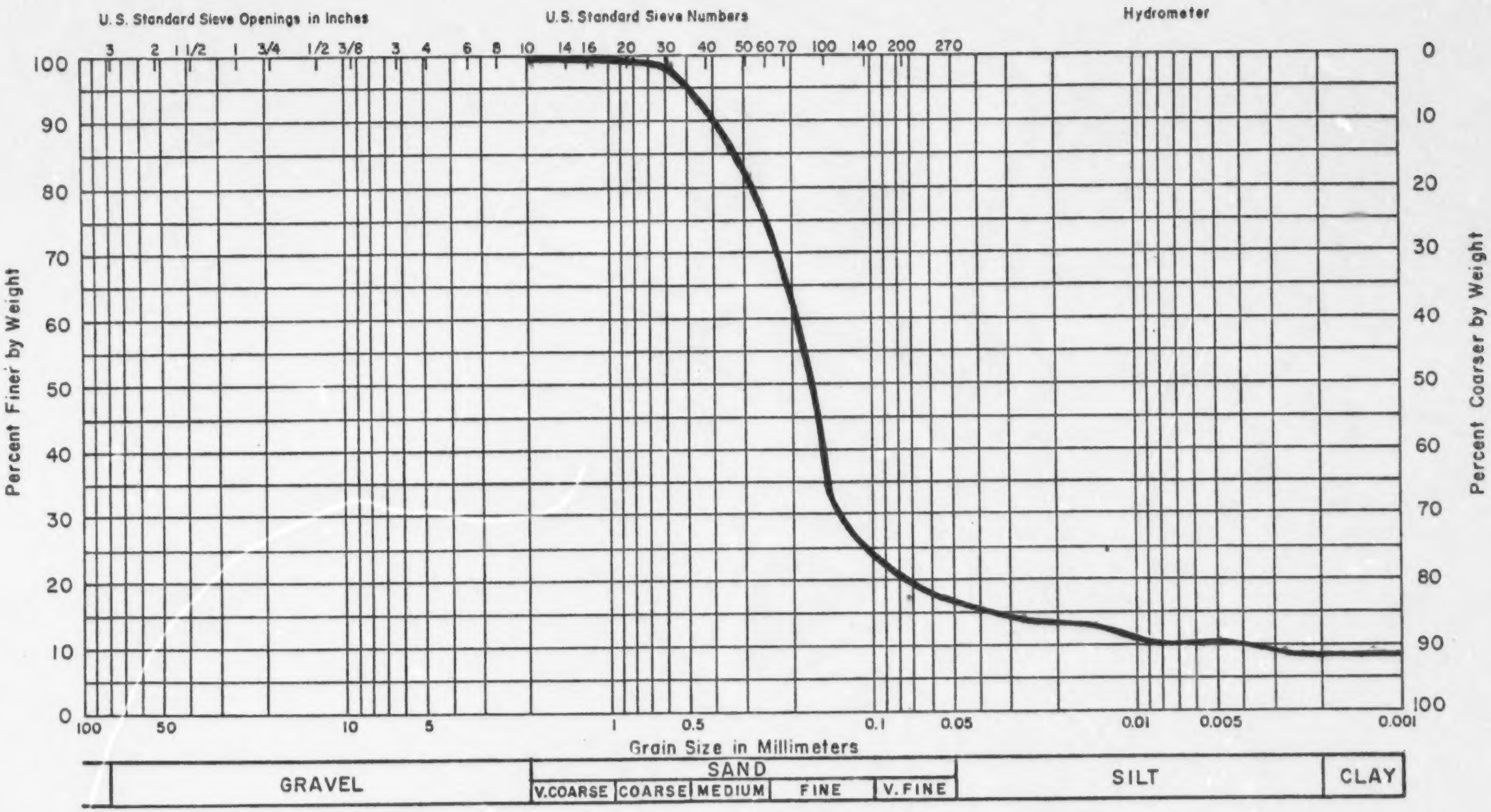
Figure 8 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
496	Macon	70	18	12	Sandy Loam
	Control				
	20-46 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

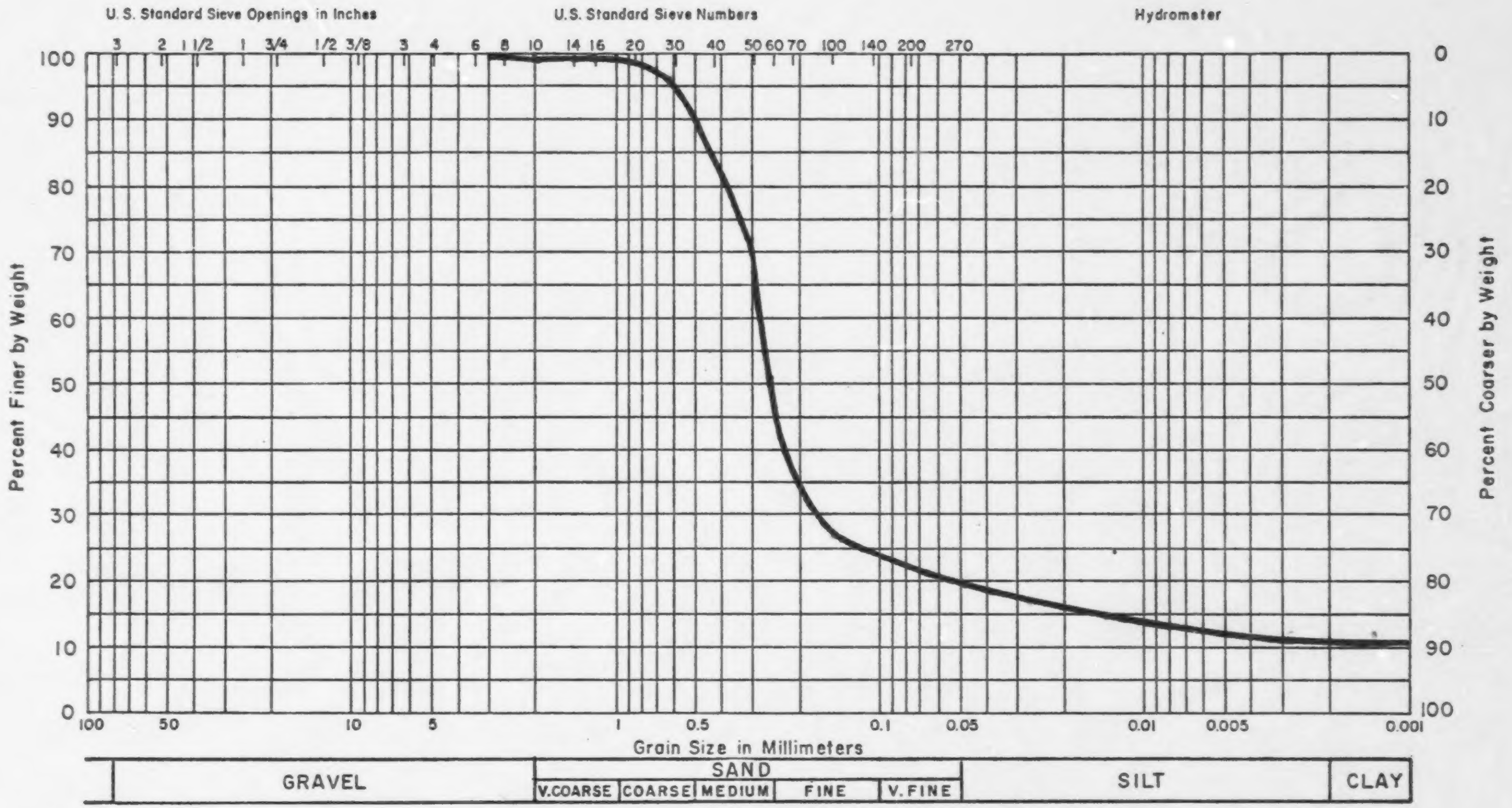
Figure 9 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
512	Macon	85	6	9	Loamy Sand
	Control				
	46-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

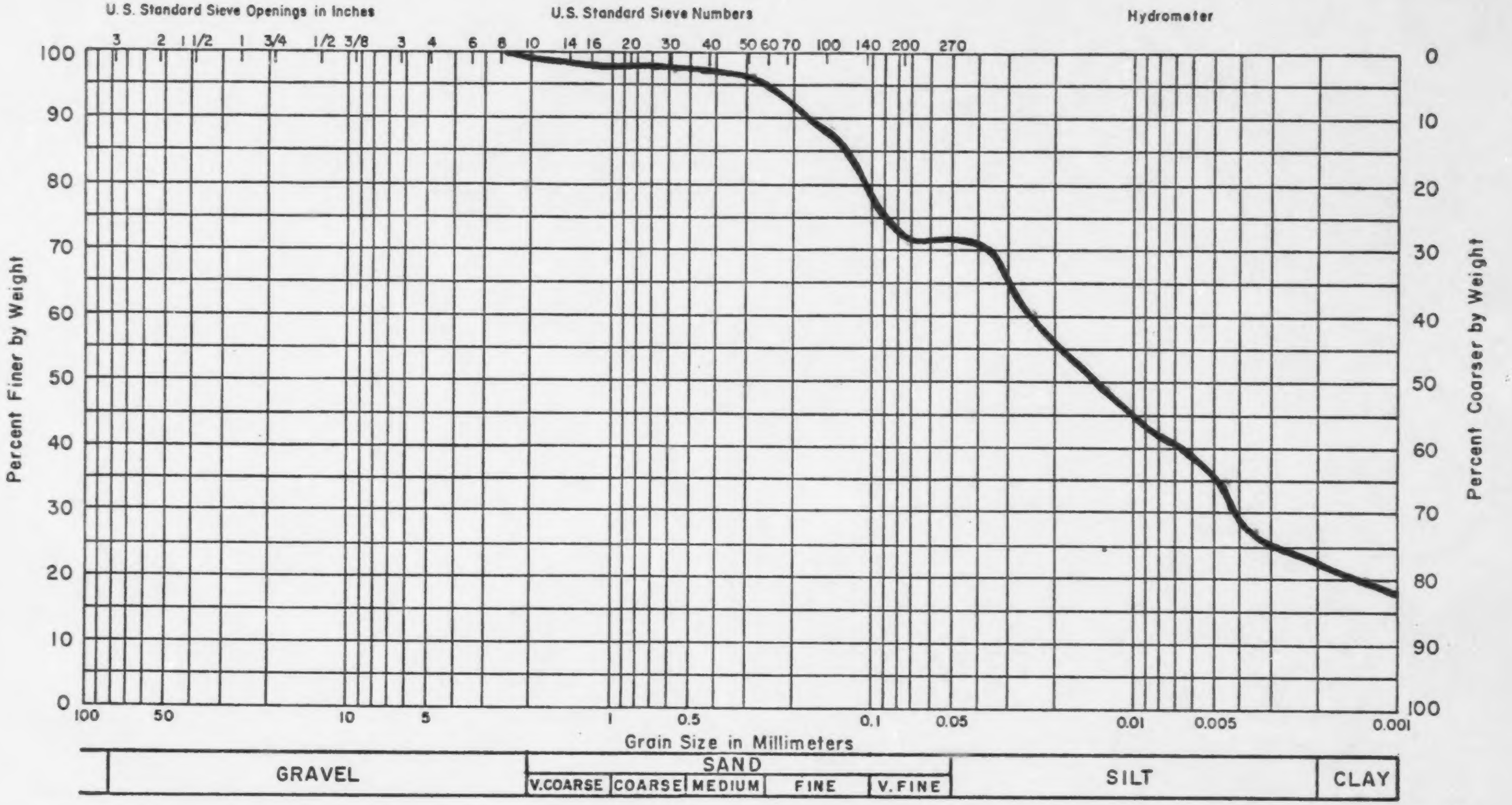
Figure 10 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
528	Macon	83	5	12	Loamy Sand/Sandy Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 11 Macon, GA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
544	Macon	29	48	23	Loam
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 12 Macon, GA, Particle Size Analysis

TABLE 13

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

MACON, GEORGIA

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . µg/kg	. . . .	
Soil			
Surface Composites	0.11	0.05	DDT
	0.56	0.04	DIELDRIN
	1.6	0.4	PCB 1221
	1.6	0.4	PCB 1248
Plant			
Composites	<0.07[1]	<0.08	DDT
	<0.03	<0.03	DIELDRIN
	<0.01	<0.01	PCB 1221
	<0.01	0.01	PCB 1248
	(4/5/76)	(10/20/76)	
Stabilized Sludge	5.85	<0.24	DDT
	<0.25	<0.04	DIELDRIN
	<0.01	5872	PCB 1221
	42.4		PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 14
PARASITES IN SLUDGES, SOILS, AND PLANTS
MACON, GEORGIA

Sample Description	Results
Sludge	
Raw (4/5/76)	Negative
Raw (10/20/76)	Negative
Stabilized (4/5/76)	*Toxocara canis*, *Ascaris lumbricoides*, *Coccidian occysts (avian)*, *Hymenolepis diminuta* -- >50 ova/gram
Stabilized (10/20/76)	Negative
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
20-46 cm	*Ascaris lumbricoides* -- < 50 ova/gram
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
20-46 cm	Negative
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 15

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
MACON, GEORGIA

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci			
		Total Org per g Sludge+	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 4/5	2.87×10^7	ND	+	-	-	ND	+	-	-	120	+	+	+	1.9×10^4	+	+	+
Raw 10/2	3.00×10^9	ND	+	-	-	ND	+	-	-	56	+	+	+	1.5×10^8	+	+	+
Stab 4/5	1.28×10^8	ND	+	-	-	ND	+	-	-	470	+	+	+	5.33×10^5	+	+	+
Stab 10/2	1.43×10^{10}	ND	+	-	-	ND	+	-	-	3,100	+	+	+	6.9×10^7	+	+	+
Plants																	
Treated	1.48×10^9	ND	+	-	-	ND	+	-	-	ND	+	-	-	3.8×10^3	+	+	+
Control	1.79×10^{10}	ND	+	-	-	ND	+	-	-	ND	+	-	-	2.00×10^2	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

TABLE 15 (continued)

Sample Description	Total Aerobic Bact per g Sludge (10^6)	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites																	
Surface	17.1	ND	+	-	-	ND	+	-	-	ND	+	-	-	14	+	+	+
20-46 cm	8.6	ND	+	-	-	ND	+	-	-	ND	+	-	-	517	+	+	+
46-61 cm	12.6	ND	+	-	-	ND	+	-	-	ND	+	-	-	505	+	+	+
61-91 cm	10.7	ND	+	-	-	ND	+	-	-	ND	+	-	-	508	+	+	+
91-122 cm	1.9	ND	+	-	-	ND	+	-	-	ND	+	-	-	380	+	+	+
Soils - Control Composites																	
Surface	3.18	ND	+	-	-	ND	+	-	-	ND	+	-	-	205	+	+	+
20-46 cm	4.14	ND	+	-	-	ND	+	-	-	ND	+	-	-	92	+	+	+
46-61 cm	6.15	ND	+	-	-	ND	+	-	-	ND	+	-	-	198	+	+	+
61-91 cm	13.0	ND	+	-	-	ND	+	-	-	ND	+	-	-	529	+	+	+
91-122 cm	11.7	ND	+	-	-	ND	+	-	-	ND	+	-	-	240	+	+	+

[1] All results expressed on a dry weight basis.

*Values expressed as a power of 10 (i.e., 10^4).

**Observations reported as + or -.

ND = none detected.

CHAPTER II

LAS VIRGENES, CALIFORNIA

SITE DESCRIPTION

Location

This study site, known as Claretville Farms, is located approximately 56 km (35 mi) west of downtown Los Angeles, California. The site is about 6 km (3.5 mi) from the Pacific Ocean. Major residential communities in the vicinity of the study site are located approximately 16 km (10 mi) northeast in the San Fernando Valley.

Sludge is received from the Tapia Water Reclamation Plant (STP) located approximately 3 km (2 mi) south of the site.

The study site itself is comprised of 85.5 ha (211 acres) of semi-mountainous terrain. This property, originally a Catholic seminary, is currently used as a campus of a small college, though portions of the property are used for agricultural purposes. The property is to be sold and converted to a cemetery. Both the sludge treated and control plots are located on the property.

Physical Condition

The Las Virgenes Valley is characteristic of the many valleys within the Santa Monica Mountain range. The site is surrounded by mountains to an elevation of 861 m (2,824 ft). Both the treated and control fields are on rolling terrain typified by slopes ranging from an estimated two to four percent.

The treated and control plots (see Figures 13 and 14) are separated by the main campus driveway. The treated plot is located to the west of the road; the control to the east. Of the total acreage on the property, only 13 ha (32 acres) are used for agricultural purposes. Of these, a total of 7.3 ha (18 acres) have been treated with sludge, half of which have had heavy applications. The treated plot is located within the latter half.

Las Virgenes Creek runs in a north-south direction and cuts through the entire Las Virgenes Valley. The stream bed is located approximately 457 m (1,500 ft) to the west of the treated plot. A smaller seasonal tributary runs in a northeast-southwest direction and empties into Las Virgenes Creek. It is located approximately 0.8 km (0.5 mi) east of the site. Both the treated and control plots drain to Las Virgenes Creek.

There are shallow swales located throughout the property which are characteristic of natural drainage patterns from the surrounding mountains. The treated plot, measuring approximately 76 x 110 m (250 x 360 ft), has one swale (see Figure 13) running diagonally from northeast to southwest. This swale, with an estimated 1 m (3 ft) deep depression, is characterized by a poorer growth of rye grass.

The field in which the control plot is located is approximately 5.7 ha (14 acres) and had been planted in oats in December, 1975. However, in order to facilitate this current study, the plot was harrowed; and on January 26, 1976, rye grass (same

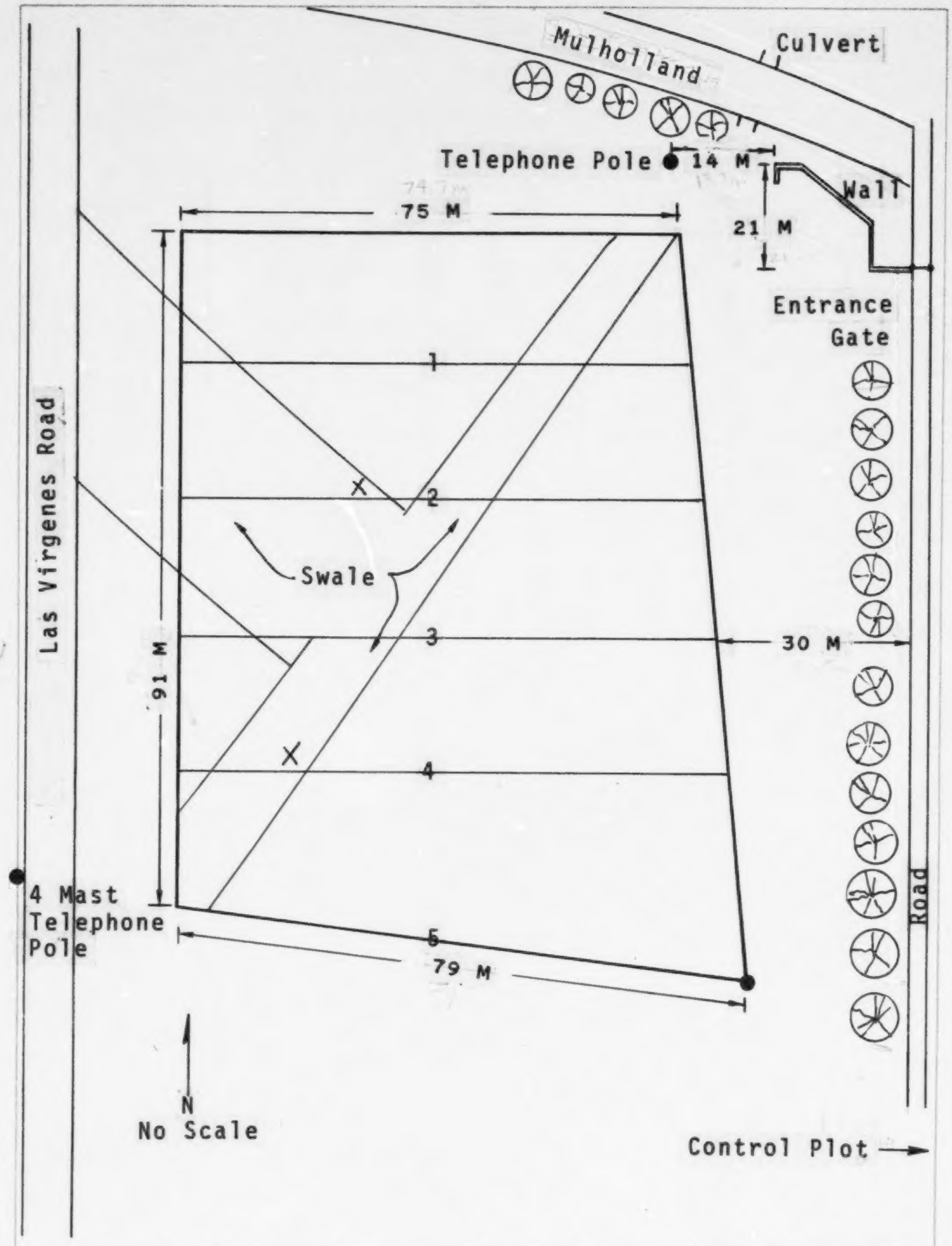

Mulholland
Culvert
Telephone Pole
14 M
Wall
21 M
74.7m
75 M
Entrance Gate
1
2
Swale
3
30 M
91 M
4
Las Virgenes Road
4 Mast Telephone Pole
5
79 M
Road
N
No Scale
Control Plot →

Figure 13 Las Virgenes, California Treated Plot

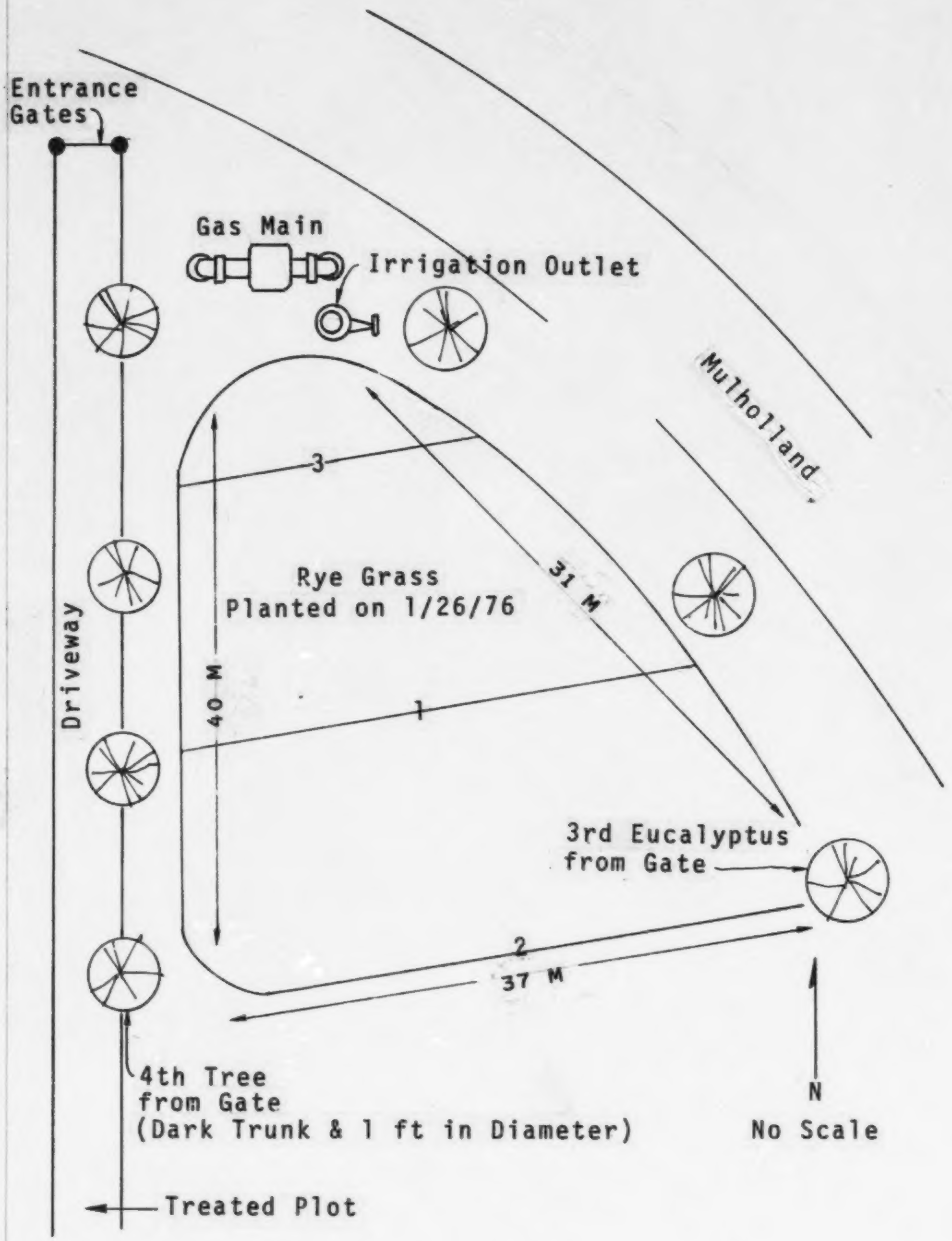

Entrance Gates
Gas Main
Irrigation Outlet
Mulholland
3
Rye Grass
Planted on 1/26/76
31 M
Driveway
40 M
1
3rd Eucalyptus
from Gate
2
37 M
4th Tree
from Gate
(Dark Trunk & 1 ft in Diameter)
N
No Scale
Treated Plot

Figure 14 Las Virgenes, California Control Plot

lot of seed as in treated plot) was planted.

The sampled area of the control plot is triangularly shaped, 39.6 x 305 x 36.6 m (130 x 100 x 120 ft).

Groundwater in two wells on the property is at an estimated depth of 213 m (700 ft) below the ground surface. The California State Department of Public Health, however, ordered that the use of these wells be discontinued prior to use of secondary effluent from the Tapia STP as an irrigation source.

Farming Practices

The treated field had been continuously planted in sudan grass - an annual crop used for cattle feed - from 1952 to 1975. In the fall of 1975, however, the 7.3 ha (18 acre) field was planted to perennial rye grass (*Lolium perrene*, variety - Linn). At the time of sampling, April 15, 1976, the rye grass on the treated plot ranged in height from 15 to 40 cm (6 to 16 in). The root zone throughout the entire plot was observed to extend to a depth of 15 to 20 cm (6 to 8 in). Growth in the swales was lower and thinner than in other sections.

The STP does not have a permit to discharge secondary effluent to a receiving stream. Consequently, a water reclamation program was established in which various ranchers throughout the Las Virgenes Valley utilize treated sewage effluent as an irrigation source. Rainfall is generally sparse, and irrigation provides moisture to support crop growth. Both the treated and control fields have been irrigated with secondary effluent since 1970.

Table 16 shows the 1975 summary of secondary effluent chemical analyses for the STP. The quantity of effluent applied to the study site is not known.

The control field has had a history of alfalfa prior to 1974. Beginning that year and continuing through the present, the field has been in oats. At the time of first sampling in April, 1976, the growth of grass on the control plot was about 6 cm (2.5 in) in height. The grass was sampled again in September, 1976.

Both the treated and control fields were prepared for planting in a similar manner. A chisel plow was used to break the ground to a depth of 45 to 50 cm (18 to 20 in), followed by disking.

Sludge, dewatered at the STP and air dried at the farm site for at least 60 days, was distributed to the field using a dump truck with the tailgate partially opened. The dried sludge was then further spread as evenly as possible with a "drag" followed by discing. A manure spreader had been tried, but the sludge proved too fine for distribution without excessive dust.

Records on the amount of sludge spread since 1969 have not been maintained by the farm manager but were provided by the STP (see Table 17). Assuming that approximately 75 percent of the dried sludge was applied to 3.6 ha (9 acres) of the treated field, the average application rate over the past three years has been approximately 51 dry m tons/ha/year (23 dry tons/

TABLE 16

TAPIA WATER RECLAMATION PLANT
1975 CHEMICAL ANALYSIS SUMMARY
SECONDARY EFFLUENT

Parameter	Result	Parameter	Result
BOD - influent	342 mg/l	Arsenic	0.002 mg/l
SS - influent	353 mg/l	Mercury	0.0002 mg/l
BOD - effluent	3 mg/l	Silver	0.001 mg/l
SS - effluent	3 mg/l	Cyanide	<0.001 mg/l
Settleable Solids	<.1 ml/l	Selenium	0.012 mg/l
Temperature	71°F	Nickel	0.036 mg/l
Ammonia Nitrogen	1.0 mg/l	Flouride	0.41 mg/l
Nitrite Nitrogen	0.10 mg/l	Boron	0.66 mg/l
Nitrate Nigrogen	14.5 mg/l	Phenolics	<0.01 mg/l
Total Nitrogen	16.8 mg/l	Zinc	0.11 mg/l
MBAS	0.10 mg/l	Lead	0.051 mg/l
O&G	0.4 mg/l	Chromium	0.005 mg/l
Phosphate	29.9 mg/l	Copper	0.05 mg/l
pH	7.3 mg/l	Cadmium	0.007 mg/l
Chloride	102 mg/l	Total Chlorinated hycrocarbons	
Sulfate	247 mg/l		<0.001 mg/l
TDS	880 mg/l	PCB's	0
Conductivity	1022 µmho	Total Coliform	<2 MPN
COD	29 mg/l	Fecal Coliform	<2 MPN
Turbidity	1.6 J.T.U.	Fecal Strep.	<2 MPN

TABLE 17

LAS VIRGENES, CALIFORNIA SLUDGE DISPOSAL (dry metric tons)[1]

Disposal Area	1969-1972	1973	1974	1975
Claretville Farms (study site)	Unknown	290	415	35
Sampo Ranch	"	303	503	1,160
Tapia Plant	"	40	27	33
20th Century Ranch	"	57	--	47
Los Angeles County Landfill	"	10	7	35
Monte Nido	"	3	--	--
Total		703	952	1,310

[1] Sludge @ 10 percent solids.

acre/year). Total sludge applied since 1969 on this field was 713 dry m tons (786 dry tons). Additional quantities of sludge have been spread on the surrounding areas of the field, but not on the sampled plot.

This study site, therefore, serves a threefold function. It is, at one time, one of several fields in the Las Virgenes Valley onto which the STP can release secondary effluent. At the same time, the rye grass serves as pasture for cattle. Thirdly, it serves as one of several locations for receipt of dewatered sludge from the STP.

Fertilizers have never been used on either the treated or control plots. The farm manager recalled that the herbicide 2-4D was used once on the control field 12 to 14 years ago. No pesticides have been used.

The cattle are used for beef production only. The farm manager stated that the livestock are healthy and show no signs of adverse effects from the sewage sludge application.

CLIMATE

The Southern California coastal climate is normally pleasant and mild throughout the year. The Pacific Ocean is the primary moderating influence, while coastal mountain ranges buffer against extremes of summer heat and winter cold from interior regions. A variable balance between mild sea breezes and either hot or cold winds from the interior provides some variety in weather conditions.

Both high and low temperatures become more extreme and the average relative humidity becomes lower as one travels inland and up foothill slopes. At the coast and on the lower coastal plain, average daily temperatures fluctuate about 15°C in summer and 20°C in the winter, but in foothill and inland valley communities these ranges increase to about 30°C in summer and 25°C in winter.

Most rainfall occurs during the winter with nearly 85 percent of the annual total occuring from November through March. Summers are essentially without precipitation. Based on records dating from 1936, the average annual precipitation has been 35.7 cm (14.05 in) with a high of 79.5 cm (31.28 in) in 1941, and a low of 10.4 cm (4.08 in) in 1953. The average annual frost-free season is approximately 320 days. Snow and thunderstorms are very infrequent. Meteorological data are summarized in Table 18.

SOIL DESCRIPTION

Regional Area

Both the sludge treated and control fields are characterized by the silty clay loam of the Salinas series. This very deep, well-drained soil developed on gentle to moderately sloping fans and valley floors in recent alluvium from sedimentary materials. Soil of this series is characterized by a dark gray, moderately fine textured, granular, neutral surface soil. Subsoil is generally dark yellowish brown, of moderately fine textures, massive, and mildly alkaline. Yellowish brown,

TABLE 18

LAS VIRGENES, CALIFORNIA

Meteorological Data For The Current Year

Station: LOS ANGELES, CALIFORNIA   Standard time used: PACIFIC   Latitude 34° 03' N   Longitude: 118° 14' W   Elevation (ground) 270 feet   Year 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches					
	Averages			Extremes						Water equivalent			Snow, Ice pellets		
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date
JAN	68.2	47.0	57.6	88	14	36	29	243	21	0.12	0.07	27	0.0	0.0	
FEB	64.1	47.4	55.8	80	24	40	22	254	0	3.54	1.84	2-3	0.0	0.0	
MAR	62.9	48.4	55.7	74	3	41	14	283	0	4.83	1.70	5-6	0.0	0.0	
APR	63.4	48.6	56.0	76	29	39	7	262	0	1.53	0.56	5-6	0.0	0.0	
MAY	70.3	55.1	62.7	80	12	50	21	75	11	0.09	0.09	20	0.0	0.0	
JUN	73.2	58.1	65.7	85	26	53	20	21	48	0.00	0.00		0.0	0.0	
JUL	81.7	63.3	72.5	90	10	60	4	0	241	0.00	0.00		0.0	0.0	
AUG	81.4	62.3	71.9	93	7	58	28	0	221	0.00	0.00		0.0	0.0	
SEP	83.2	64.7	74.0	102	24	59	3	0	277	0.00	0.00		0.0	0.0	
OCT	75.1	57.7	66.4	93	4	50	26	31	82	0.27	0.17	11	0.0	0.0	
NOV	71.6	50.8	61.2	86	13	40	30	132	26	0.00	0.00		0.0	0.0	
DEC	67.9	46.0	57.0	83	8	37	15	247	4	0.32	0.32	12	0.0	0.0	
YEAR	71.9	54.1	63.0	102	SEP 24	36	JAN 29	1548	931	10.70	1.84	FEB 2-3	0.0	0.0	

Month	Relative humidity, pct.				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Hour	Hour	Hour	Hour	Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F				
																				Maximum		Minimum		
	04	10	16	22	Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy					(b) 90° and above	32° and below	32° and below	0° and below	Elev. 0 feet m.s.l.
	(Local time)																							
JAN								22	NW	9	83	3.0	18	9	4	2	0			0	0	0	0	
FEB								25	NW	14	76	4.9	9	10	9	6	0			0	0	0	0	
MAR								27	NW	26		5.3	12	5	14	12	0			0	0	0	0	
APR								21	NW	26	80	4.8	12	9	9	8	0			0	0	0	0	
MAY								23	SW	4	85	5.0	9	15	7	1	0			0	0	0	0	
JUN								14	SW	2	82	6.1	7	11	12	0	0			0	0	0	0	
JUL								14	SW	13	91	3.3	19	11	1	0	0			1	0	0	0	
AUG								13	SW	13		2.4	24	7	0	0	0			1	0	0	0	
SEP								13	SW	30		3.6	18	7	5	0	0			6	0	0	0	
OCT								20	SW	6	73	3.4	17	8	6	3	0			2	0	0	0	
NOV								26	SW	28	79	2.6	21	5	4	0	0			0	0	0	0	
DEC								23	NW	31	73	2.5	23	5	3	1	0			0	0	0	0	
YEAR								27	NW	MAR 26	60	3.9	189	102	74	33	0			10	0	0	0	

(70)

TABLE 18 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches											Relative $ humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days											Average station pressure mb.
	Normal			Extremes						Water equivalent							Snow, Ice pellets				Hour 04	Hour 10	Hour 16	Hour 22			Fastest mile					Sunrise to sunset							Temperatures °F				Elev.
																					(Local time)																		Max.		Min.		
Month	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year					Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	feet m.s.l.
(a)				35		35					35		35		35		35		35		17	10	23	11	24	23	35	35		32	33	33	33	33	35	35	23	23	35	35	35	35	
J	66.5	46.8	56.7	95	1971	28	1949	268	10	3.00	14.94	1969	0.00	1972	6.11	1956	0.3	1949	0.3	1949	83	51	50	67	6.8	NE	49	N	1946	69	4.5	14	8	9	6	0	1	2	*	0	*	0	
F	67.6	48.5	58.1	91	1971	34	1949	207	14	2.77	12.42	1941	T	1964	4.02	1944	T	1951	T	1951	71	54	52	70	6.9	W	40	NW	1961	72	4.7	12	7	9	5	0	1	2	*	0	0	0	
M	68.6	49.8	59.2	94	1972	38	1971	190	10	2.19	8.14	1941	0.00	1959	3.41	1943	0.0		0.0		74	52	52	72	7.0	W	47	NW	1964	73	4.7	13	9	9	6	0	1	1	*	0	0	0	
A	70.5	52.9	61.7	99	1966	39	1975	124	25	1.27	6.02	1965	0.00	1973	2.05	1956	0.0		0.0		78	53	54	74	6.6	W	40	NW	1955	70	4.7	12	10	8	4	0	1	1	1	0	0	0	
M	73.2	56.1	64.7	102	1967	46	1964	60	51	0.13	1.43	1955	0.00	1970	1.07	1955	0.0		0.0		81	56	55	75	6.3	W	39	NW	1945	66	4.8	12	11	8	1	0	*	1	1	0	0	0	
J	76.5	59.5	68.0	106	1973	50	1953	25	115	0.03	0.32	1964	0.00	1975	0.32	1964	0.0		0.0		85	59	56	78	5.7	W	32	N	1949	65	4.3	13	11	6	1	0	*	1	1	0	0	0	
J	82.9	63.5	73.2	103	1959	54	1952	0	258	0.00	0.03	1969	0.00	1975	0.03	1969	0.0		0.0		84	54	53	79	5.4	W	21	W	1947	82	2.7	21	9	1	*	0	*	1	4	0	0	0	
A	83.7	64.4	74.1	103	1967	53	1943	0	282	0.04	0.39	1958	0.00	1975	0.38	1958	0.0		0.0		84	56	55	79	5.3	W	24	E	1945	83	2.6	22	8	1	1	0	*	1	4	0	0	0	
S	82.5	62.8	72.7	110	1955	51	1948	5	236	0.17	1.80	1965	0.00	1975	1.45	1965	0.0		0.0		78	52	54	76	5.3	W	27	NW	1941	79	2.9	19	8	3	1	0	*	1	6	0	0	0	
O	78.0	58.7	68.4	104	1958	41	1971	35	140	0.27	1.53	1941	0.00	1970	0.62	1941	0.0		0.0		76	55	56	74	5.7	W	48	N	1959	73	3.8	16	9	6	2	0	*	3	3	0	0	0	
N	73.2	52.1	62.7	100	1966	39	1964	113	44	2.02	9.68	1965	0.00	1975	4.07	1970	0.0		0.0		61	45	49	62	6.4	W	42	N	1946	74	3.7	16	8	6	3	0	1	2	1	0	0	0	
D	68.0	48.1	58.1	89	1958	32	1951	218	0	2.16	6.57	1971	T	1963	3.92	1965	T	1947	T	1947	62	45	50	62	6.6	NE	44	SE	1943	71	4.3	15	8	8	5	0	1	2	0	0	*	0	
YR	74.3	55.3	64.8	110	SEP 1955	28	JAN 1949	1245	1185	14.05	14.94	JAN 1969	0.00	NOV 1975	6.11	JAN 1956	0.3	JAN 1949	0.3	JAN 1949	75	53	53	72	6.2	W	49	N	JAN 1946	73	4.0	185	106	74	34	0	6	17	20	0	*	0	

medium textured, massive, calcareous substrata underlie the subsoils.

A typical Salinas series soil profile as mapped by the Soil Conservation Service follows:

- 0 to 38.1 cm (0 to 15 in) - dark gray silty clay loam; medium granular structure; hard, slightly sticky and plastic; neutral.
- 38.1 to 78.7 cm (15 to 31 in) - dark grayish-brown clay loam; medium subangular blocky structure; hard, sticky and plastic; neutral.
- 78.7 to 106 cm (31 to 42 in) - dark yellowish-brown clay loam; massive; hard, sticky and plastic; mildly alkaline.
- 106 to 152 cm (42 to 60 in) and deeper - yellowish-brown silt loam; massive; slightly hard, slightly sticky and plastic; moderately alkaline, strongly calcareous.

The Salinas series includes about five percent each of Sorrento clay loam, Croply clay, and Salinas silty clay loam on slopes of from less than two percent to more than nine percent.

Treated Plot

The surface and subsurface soils of the treated plot generally follow the above profile for Salinas silty clay loam. The observed profile based upon sampling was relatively uniform to 121 cm (48 in) consisting of dark gray silty clay loam at

73

the surface, gradually changing by the 1.2 m (4 ft) level to dark grayish-brown clay loam. The surface soil was taken to a depth of 30 cm (12 in). A coarser, slightly yellowish-brown clay loam was encountered at areas marked "X" on Figure 13-1. This discontinuity was not observed at any other sampling holes on either the treated or control plots. Both surface and subsurface soils within the swale region were observed to be drier and less plastic than other parts of the field.

Control Plot

The surface and subsurface soils of the control area appeared to be similar to those of the treated plot.

Texture and pH data for soils obtained from the treated and control plots are shown in Table 19.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The STP currently serves an approximate population of 40,000 and a population equivalent of 75,500. Average daily flow is approximately 17,033 cu m/day (4.5 mgd).

The plant, constructed in 1965, was originally designed for a flow of 1893 cu m/day (0.5 mgd). Expansion over the last eleven years has increased its capacity to 30,280 cu m/day (8 mgd).

The plant utilizes an activated sludge process. Primary treatment consists of comminution followed by sedimentation. Primary effluent then enters the rectangular activated sludge aeration tanks. The operation is step fed with a 3.5 hour

TABLE 19 4

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

LAS VIRGENES, CALIFORNIA

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS SAND	SILT	CLAY	ORG-N	NO3-N	NH4-N (2)	PH (1)	CEC
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	19.0	1.58	23	43	34	1.48	10.20	12.90	6.5	30
30-61 CM	16.3	1.33	21	43	36	0.082	3.57	27.80	6.8	23
61-91 CM	16.0	0.89	25	36	39	0.075	5.76	18.90	6.4	20
91-122 CM	16.2	0.83	23	44	53	0.063	9.86	1.57	6.3	30
CONTROL										
SURFACE	16.7	1.40	26	39	35	1.26	3.87	5.09	7.1	30
30-61 CM	15.0	0.96	21	39	40	0.082	1.50	2.48	6.7	27
61-91 CM	15.3	0.76	26	36	38	0.077	1.47	1.57	6.2	40
91-122 CM	15.1	0.49	27	36	37	0.064	2.00	4.10	6.1	30

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

detention time. Final effluent is treated in a chlorine contact chamber and released to a 11,400 cu m (3 MG) slow equalizing reservoir.

The reclaimed water is pumped to two unlined storage reservoirs. The first reservoir located at the STP holds 11,400 cu m (3 MG) and serves as regulatory storage for waste spray disposal on non-productive agricultural land. During periods of inclement weather surplus effluent is disposed by stream discharge from the reservoirs. The STP has no permit for stream discharge, except during these periods of inclement weather. A second reservoir holds 49,200 cu m (13 MG) of reclaimed water for crop and permanent pasture irrigation and off-site waste spray fields. All fields are properly managed and irrigated throughout the year. Gravity feed from the reservoirs supplies sufficient head for irrigation.

As summarized in Table 16, the final effluent from the STP approaches drinking water quality. BOD, SS, heavy metal concentrations, and Coliform MPN values are very low. The low metals concentrations are due to stringent industrial discharge regulations.

Approximately 10 percent of the influent is contributed by industry. The major industrial contributors are Bunker Ramo, the Burroughs Corporation, Raypak, and Fotomat.

Industry monitoring has not been comprehensive in the past. TDS and pH are checked for each industrial contributor on a monthly schedule.

Sludge Stabilization and Storage

Sludge from the STP is stabilized in aerobic digestion tanks having a combined capacity of 3020 cu m (800,000 gal). Sludge is generated from a combination of settled waste activated sludge and primary sludge. Total detention time for stabilization is approximately 20 days at 3 percent solids (average). The stabilized sludge is treated with a 2 percent solution of Rohm and Haas Primafloc (a polyelectrolyte flocculating agent) dewatering in three Dual Cell Gravity (DCG) units. The solids concentration is increased to approximately 9 to 11 percent in the DCG's. The thickened sludge is belt conveyed and loaded into 5.7 cu m (7.5 cu yd) dumpsters (see Photograph 10), for transport to the various disposal sites.

The STP provides no storage capacity for sludge other than the limited flexibility of digester detention time. The moderate coastal weather permits sludge distribution on essentially an uninterrupted, year round basis. During periods of inclement weather, the sludge is brought to the county landfill because of the muddy field conditions.

On September 12, 1975, a sample of the dewatered sludge was obtained, an analysis of which is presented in Table 20. This tabulation represents the only historical data on these sludge solids. All reported metal concentrations were less than 1700 μg/g on an oven dry weight basis.

Disposal of Sewage Sludge

Table 21 presents a monthly distribution of dewatered

TABLE 20

LAS VIRGENES, CALIFORNIA - STABILIZED LIQUID SLUDGE ANALYSIS[1]

Parameter	Concentration[2]
	- $\mu g/g$ -
Cd	5.3
Cu	906
Ni	222
Zn	1,670
Pb	233
Moisture (%)	86.6

---

[1] Phase I Stabilized sludge sample, September 12, 1975.

[2] Data expressed on an oven dry weight basis.

97

TABLE 21

LAS VIRGENES, CALIFORNIA

DEWATERED SLUDGE GENERATION (1973-1975) (cu m)

Month	1973	1974	1975
Jan.	502	477	1071
Feb.	688	526	905
March	296	556	925
April	473	660	1168
May	783	673	933
June	644	832	977
July	294	1052	914
Aug.	691	1044	795
Sept.	642	642	482
Oct.	636	1009	348
Nov.	654	1095	1462
Dec.	569	691	1220
Total	6872	9257	11200

sludge for the years 1973 to 1975 inclusive. In 1975, 11,200 cu m (14,650 cu yd) were generated. This is equivalent to an annual figure of 1120 dry m tons (1230 dry tons), assuming 10 percent sludge solids, which is an average figure reported by the STP.

Historical data on sludge spreading have only been recorded since 1973 (see Table 17). As shown, the spreading is divided between a number of sites. The study site, however, is the only location where sludge is used for soil amendment purposes. The other sites do not utilize the sludge for any agricultural purposes. The only feasible alternative to these sites is disposal to a landfill which charges the STP a fee of $18 per load.

Typically, the STP distributes 8 loads of dewatered sludge daily. Each load is estimated to be 3.6 m tons (4 wet tons), equivalent to 363 kg (800 dry pounds) per load. The plant usually disposes of sludge 23 days per month on a continuous 12-month cycle.

A dump truck is used to transport wet sludge to the land sites. The sludge is dumped at designated locations for distribution by the farmers.

Utilizing a small bulldozer, the study site farm manager spreads the piles of dewatered sludge over a sufficient area to allow the sludge to air dry for a minimum of 6 months. The dried sludge is then hand-loaded into a dump truck and spread on the field (see Farming Practices for additional details).

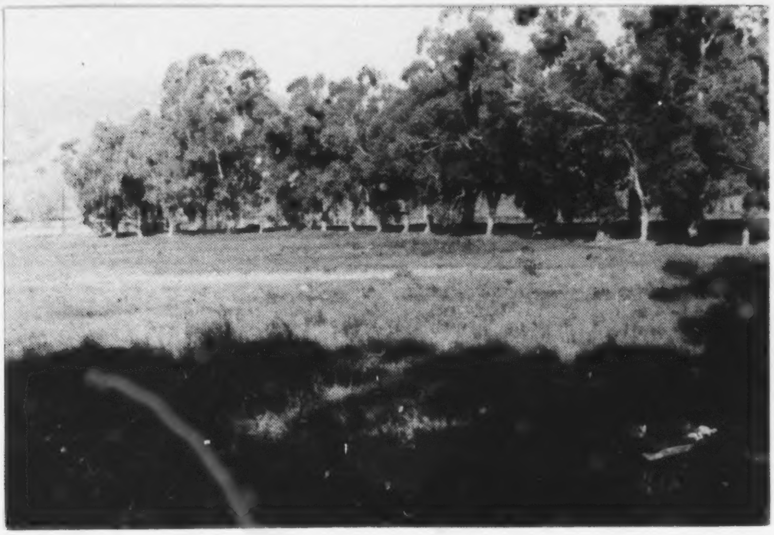
Photographs 7 through 10 show, respectively, the treated plot, control plot, DCG dewatering unit, and dumpster container.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

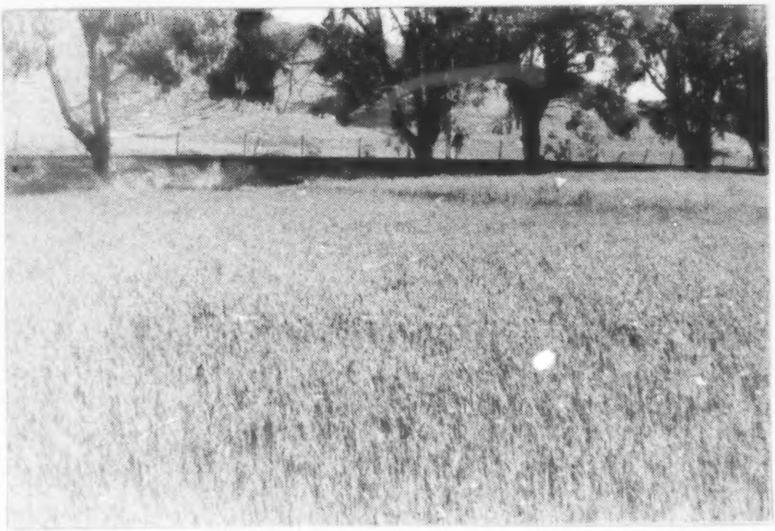
In an effort to assess public attitudes toward landspreading of sludge, the California State Public Health Department and several local newspapers were contacted. The Health Department representative stated that he recognized sludge spreading as a viable alternative for sludge disposal but expressed concern about the potential build-up of toxic materials.

A telephone interview with the editor of the Malibu Surfside News indicated that there had never been articles in the paper concerning sludge disposal. However, there is intense public concern with expansion of sewer systems in the general area. The editor stated that opposition to expansion is partially a result of the constant foul odors which permeate the Las Virgenes Valley and the aesthetic problems associated with the disposal of "anything" from a sewage treatment plant. These pressures are partly responsible for the STP currently having no discharge permit for their treated effluent.

STP personnel stated that they have tried to explain to the various objectors the nature and degree of treatment of the secondary effluent - that in most cases, it is of better quality than the water normally flowing in Malibu Creek - all to no avail.



Photograph 7
Treated Plot



Photograph 8
Control Plot

Photograph 9
DCG Dewatering Unit

Photograph 10
Dumpster

In early 1976, a complaint was registered with the Los Angeles County Air Pollution Control District. This complaint concerned odors resulting from piling of dewatered sludge close to the study site. The complaint was lodged by a resident of the area who lives in close proximity to the piled sludge site. This problem has not yet been resolved, and with the potential sale of the study site, sludge spreading at the site has been halted.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

There are no state, county or city regulations governing the application of municipal sewage sludge solids at the Las Virgenes site. The California State and the Los Angeles County public health departments are aware of the STP's sludge utilization practices. The California State Public Health Department sets guidelines to the effect that sludge spreading will not be a source of contamination to water resources, create a public health menace, or present an aesthetic nuisance, but does not require site preparation, monitoring, or specific disposal practices.

The employees of the STP receive mandatory inoculations against typhoid, tetanus, and polio.

ECONOMICS

The sludge spreading program was initiated in 1967 with the purchase of one DCG gravity sludge dewatering unit for $20,000. The dewatered sludge was hauled to various local dumping spots. This practice was continued until 1971 at which time two more DCG units were purchased at $20,000 each. Additional purchases were a 1971 Chevrolet truck for $21,000 and two Dempster containers at $1,800 each.

The STP maintains a separate, detailed accounting record for all cost centers associated with the sludge spreading operation as shown in Table 22. All data are expressed in terms of $/MG-STP influent. A cost analysis for calendar 1975 is presented in Table 23. The STP personnel are aware of the high costs and have drafted a plan to alter their disposal program accordingly. The proposed alternative encompasses the purchase of nearby land and the piping of liquid sludge solids to the disposal site. This would eliminate the high chemical and hauling costs.

SAMPLING AND ANALYSIS

Sludge

On April 15 and August 4, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the aerobic digesters.

Soil

On April 15 and April 23, 1976, surface soil samples were taken from both the treated and control plots. These plots were divided into five and three sections, respectively (refer to Figure 13 and 14. The control plot was divided into only three sections because of its smaller size.

Thirty (30) random surface soil samples from 0 to 25 cm (0 to 10 in)were taken in each section using a 2.5 cm (1 in)

TABLE 22

LAS VIRGENES, CALIFORNIA
DIGESTION, DEWATERING, AND SPREADING COSTS - 1975

Cost Center	Rate[1]
STP Labor	16
Energy	45
Hauling - 58% Labor 42% Equipment	11
Dumping Fees	8
Maintenance and Parts	7

---

[1] Expressed in terms of \$/mg STP influent.

TABLE 23

COST FOR DISPOSAL OF DEWATERED SLUDGE - 1975

Annual Capital Cost	
Vehicle Depreciation[1]	
1971 Chevrolet Truck: $21,000	$ 3,563
Equipment Depreciation[2]	
3 - DCG Units: $60,000	8,734
2 - Dempster Dumpsters: $3,600	524
Total Annual Capital Cost	$12,821
Annual Operating Cost	
Personnel	
Plant Labor	$26,640
Hauling Labor	10,664
Total Labor	$37,304
Fringe Benefits (30 percent)	$11,191
Vehicle & Equipment Maintenance & Operation	19,306
Dumping Fees	13,320
Chemicals	34,965
Utilities	998
Total Annual Operating Cost	$117,084
Total Annual Capital & Operating Cost	$129,905
10 Percent Contingency Factor[3]	$ 13,000
Total Annual Cost	$142,905

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$142,905}{1,230\text{ dry tons}} = \$128.07/\text{dry m ton}\ (\$116.18/\text{dry ton})$$

---

[1] Vehicle was fully depreciated over 8 years assuming 8 percent interest equivalent to $169.68/$1,000 annually.

[2] Equipment was fully depreciated over 10 years at 8 percent interest, equivalent to $145.56/$1,000 annually.

[3] A 10 percent contingency factor is added as administrative overhead.

diameter stainless steel split tube sampler. As the sampler was withdrawn, any miscellaneous nonrelated debris was discarded prior to placing the soil into a sampling bag.

Subsurface samples were obtained with a 7.6 cm (3 in) diameter steel bucket auger and split tube sampler. The subsurface samples were so moist and plastic that the bucket auger would penetrate only a few centimeters at a time. To make matters worse, once the soil was in the bucket auger, the sample could be removed only with great difficulty. At the start, therefore, of each subsurface layer, the bucket auger was used to remove soil to the beginning layer depth. The split tube sampler, fitted with 30 cm (1 ft) extensions, was then inserted at three different spots in the hole. Each of these three samples was saved to represent that particular depth. Samples obtained from 30 to 61 cm (12 to 24 in) were labeled "A"; those from 61 to 91 cm (24 to 36 in) as "B"; and from 91 to 121 cm (36 to 48 in) as "C."

Plants

Plant samples from the treated area were obtained on April 15, 1976. The control field was not sampled until September 27, 1976, due to the late planting date (January 26, 1976).

Plant samples from both the treated and control plots were obtained by shearing and retaining that portion of the rye grass above a height of 15 to 17 cm (6 to 7 in). Each sampling from a section produced about 0.9 kg (2 lb) of sample.

Tables 24 through 30 present the following:

Table	Description
24	Chemical Characterization of Stabilized Sludges
25	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
26	Total Metal Concentrations in Individual Subsurface Soil Samples
27	Metal Concentrations in Surface Soils and Plants
28	Chlorinated Hydrocarbon Concentrations in Sludge, Soils and Plants
29	Parasites in Sludges, Soils, and Plants
30	Concentrations of Microbes in Sludges, Soils, and Plants

Figures 15 to 22 present particle size analyses of the various soil composites by depth.

TABLE 24

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM LAS VIRGENES, CALIFORNIA

	4/15/76	8/4/76	Average	Field Dried
Volatile Solids (%)	77.38	72.06	74.7	63.95
NO_3 - N	.15	<0.67	.41	4.19
NH_4 - N	1640	4665	3153	2224
Organic N	48859	41539	45199	47065
P	18167	16067	17117	17814
K	1086	20.45	1566	1344
Na	1379	2629	2004	2063
Ca	25955	27000	26478	23217
Mg	5116	4674	4895	5206
SO_4	67.3	96.0	81.7	1159
Cl	1040	1910	1475	1067
Ag	5.55	1.35	3.45	.78
As	1.62	6.63	4.13	8.2
B	70.2	73.0	71.6	73.0
Cd	11.6	10.6	11.1	11.9
Cr	185	122	154	211
Co	3.79	8.99	6.39	10.3
Cu	939	964	952	953
Fe	6768	7067	6918	9813
Hg	90.4	7.53	49.0	2.0
Mn	542	420	481	550
Mo	6.67	13.8	10.2	12.5
Ni	64.6	46.1	55.4	101
Pb	36.9	42.7	39.8	73.7
Se	5.05	8.99	7.02	13.0
Zn	1379	1326	1353	1456
H_2O (%)	88.3	91.1	85.6	3.7
pH	6.9	6.3		

All units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 25

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

LAS VIRGENES, CALIFORNIA

PLOT/ DEPTH:	TOTAL METALS (2)					DTPA EXTRACTABLES			
	CD	CU	NI	ZN	PB	CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	3.58	45.4	52.9	120.[illegible]	21.7	1.48	5.41	2.51	8.12
30-61 CM.	3.79	29.1	50.3	93.4	19.3	1.21	2.06	2.30	0.42
61-91 CM.	3.41	28.5	49.5	93.8	19.0	1.23	2.47	2.99	0.31
91-122 CM.	3.53	28.5	50.2	90.7	18.7	1.35	2.89	3.07	0.80
CONTROL									
SURFACE	3.77	27.7	48.0	98.1	19.9	1.37	1.69	1.45	1.01
30-61 CM.	3.75	27.6	50.5	94.2	19.7	1.37	2.31	2.37	0.89
61-91 CM.	3.22	28.0	50.2	90.2	19.9	1.53	2.50	3.22	0.85
91-122 CM.	4.11	28.1	52.8	90.9	20.6	1.65	2.37	3.15	0.60

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 26

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES (1)

LAS VIRGENES, CALIFORNIA

SECTION/ DEPTH	TREATED				CONTROL			
	CD	CU	NI	ZN	CD	CU	NI	ZN
	µG/G				µG/G			
SECTION 1								
30-61 CM.	2.76	29.5	51.9	101	3.99	27.2	51.6	99.5
61-91 CM.	3.27	26.7	48.8	90.0	3.82	27.2	50.4	96.6
91-122 CM.	3.72	29.3	53.5	96.2	3.97	26.0	49.6	89.1
SECTION 2								
30-61 CM.	3.05	29.0	51.9	96.9	4.03	26.4	50.4	97.4
61-91 CM.	2.99	27.4	47.8	95.6	3.80	28.2	49.0	90.9
91-122 CM.	3.27	30.0	50.5	94.0	4.41	27.2	48.3	94.9
SECTION 3								
30-61 CM.	3.40	29.5	50.5	97.6	3.13	26.6	45.9	89.8
61-91 CM.	3.87	27.9	49.3	87.0	3.33	26.4	46.8	93.4
91-122 CM.	3.34	27.9	49.2	87.1	3.46	26.6	47.6	89.4
SECTION 4								
30-61 CM.	3.46	30.2	50.7	97.3				
61-91 CM.	3.27	28.6	50.0	91.6				
91-122 CM.	3.06	28.0	48.1	95.0				
SECTION 5								
30-61 CM.	3.02	28.0	48.7	92.1				
61-91 CM.	3.27	30.2	51.3	97.7				
91-122 CM.	3.32	27.4	49.3	89.8				

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 27

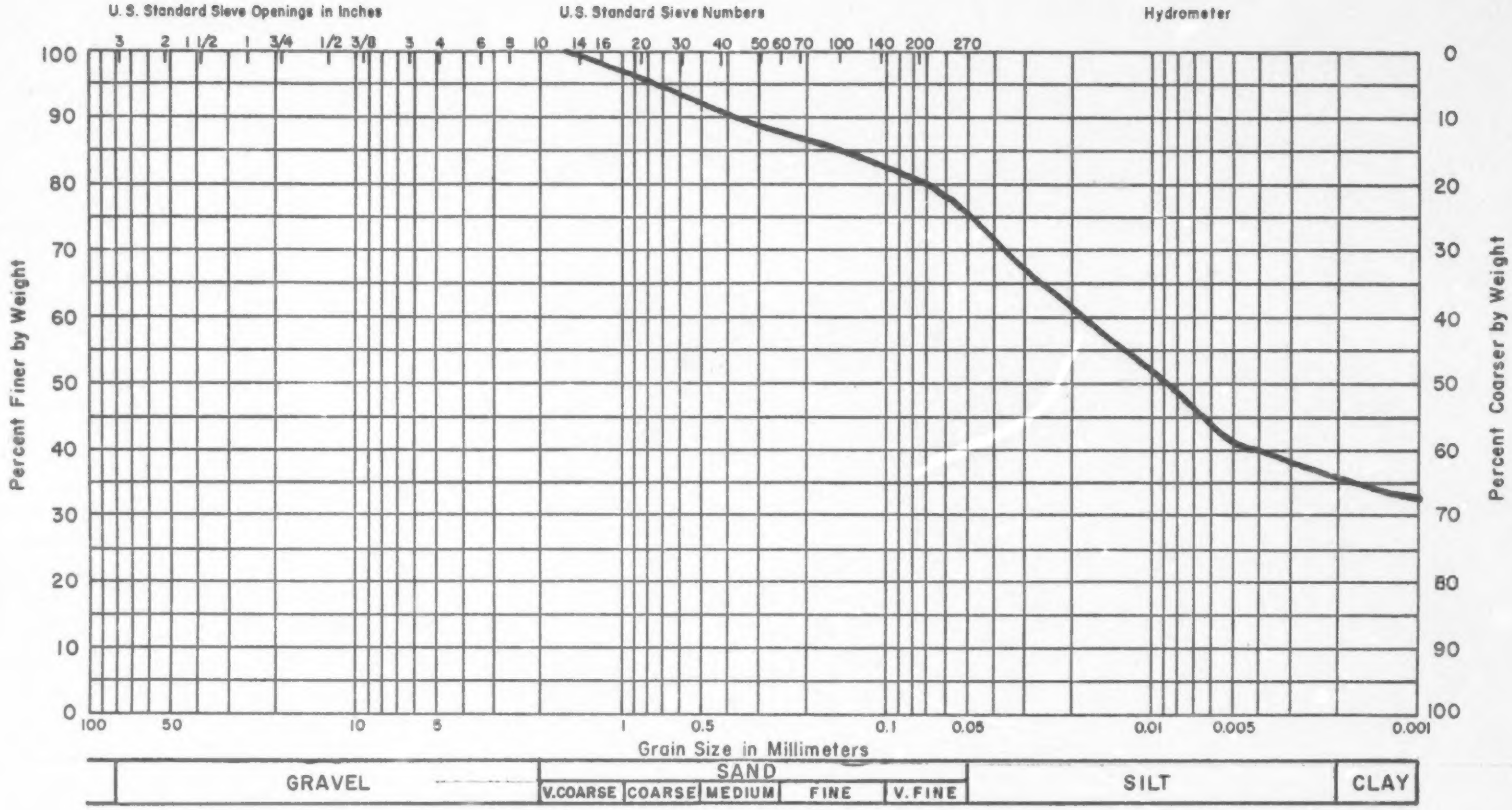
METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS(1)

LAS VIRGENES, CALIFORNIA

SAMPLE	SURFACE SOIL					PLANT					
	CD	CU	NI	ZN	PB(2)	CD	CU	NI	ZN	PB(2)	ORG-N(2)
	μG/G					μG/G					
TREATED											
COMPOSITE	3.58	45.4	52.9	120	21.7	0.72	12.5	7.80	60.0	14.6	4.17
SECTION 1	4.03	56.2	54.7	143		0.44	13.9	9.30	60.4		
SECTION 2	3.85	51.3	53.3	134		0.52	9.53	10.5	51.0		
SECTION 3	5.15	45.4	53.2	127		0.89	13.3	8.48	77.0		
SECTION 4	3.60	40.4	52.8	117		0.78	10.4	7.38	58.6		
SECTION 5	3.39	36.2	52.3	117		0.72	9.68	9.37	45.5		
MEAN	4.00	45.9	53.3	128		0.67	11.4	9.01	58.5		
STD. DEV.	0.69	8.06	0.90	11.2		0.19	2.08	1.16	12.0		
CONTROL											
COMPOSITE	3.77	27.7	48.0	98.1	19.9	1.56	11.5	4.25	70.0	8.40	0.64
SECTION 1	3.76	27.3	49.2	99.5		1.79	11.1	5.43	71.3		
SECTION 2	4.21	28.0	50.8	99.0		1.11	10.3	5.69	57.7		
SECTION 3	3.67	26.3	49.4	92.9		1.34	10.2	4.13	54.2		
MEAN	3.88	27.2	49.8	97.1		1.41	10.5	5.08	61.1		
STD. DEV.	0.29	0.85	0.87	3.68		0.35	0.49	0.84	9.03		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

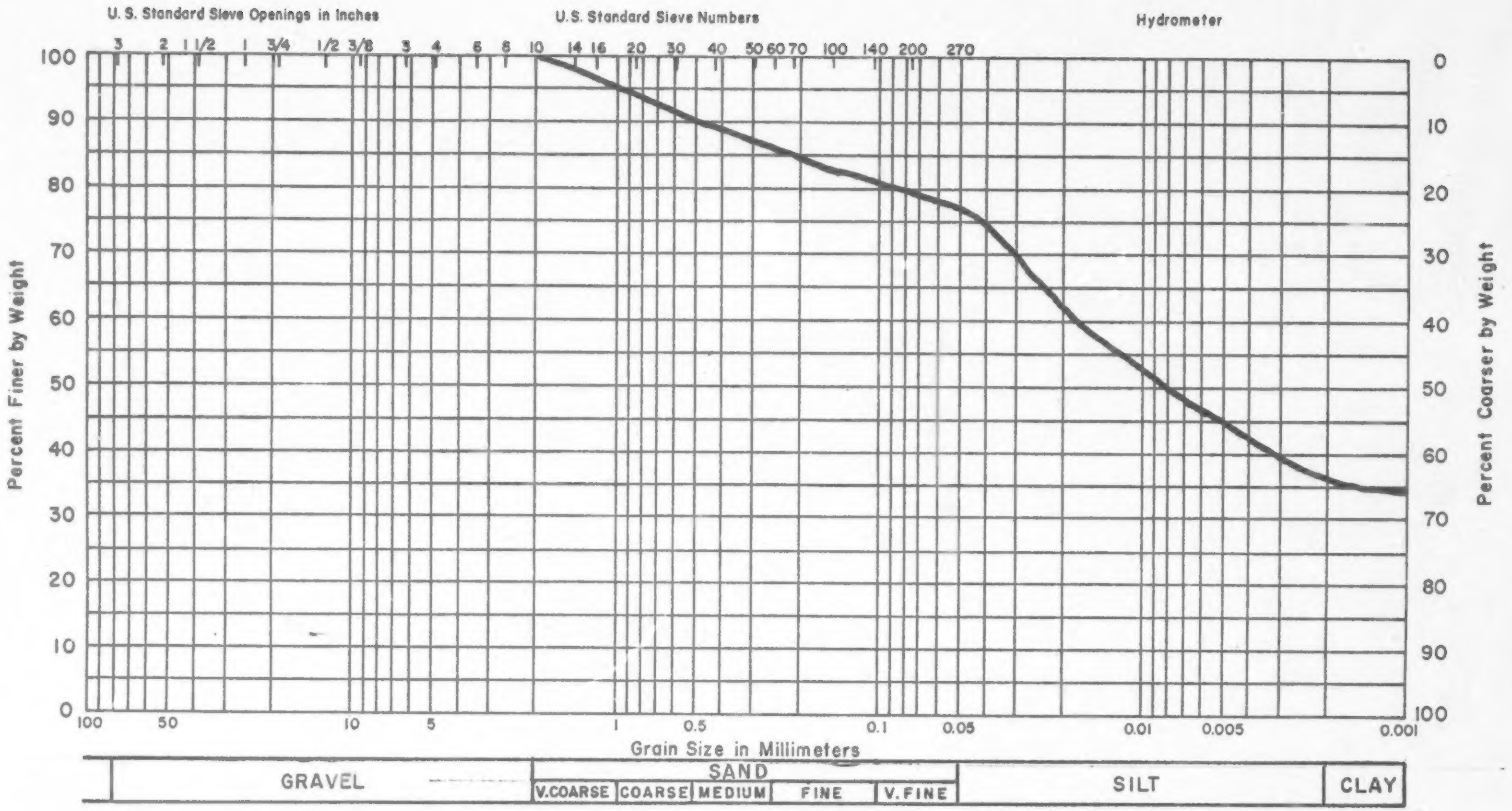
(2) ANALYSIS ON COMPOSITE ONLY.



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
639	Las Virgenes	23	43	34	Clay Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

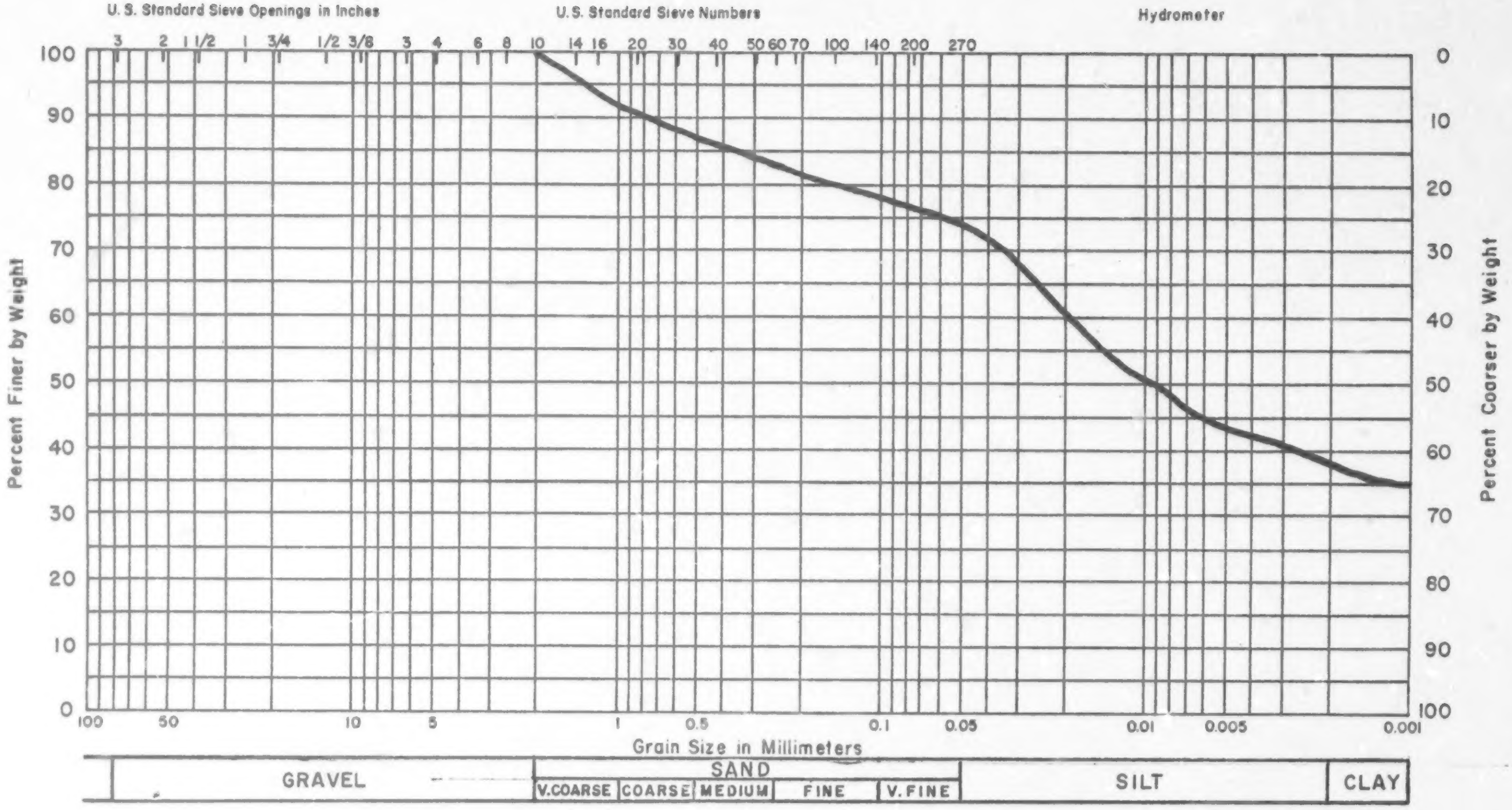
Figure 15 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
638	Las Virgenes	21	43	36	Clay Loam
	Treated				
	31-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

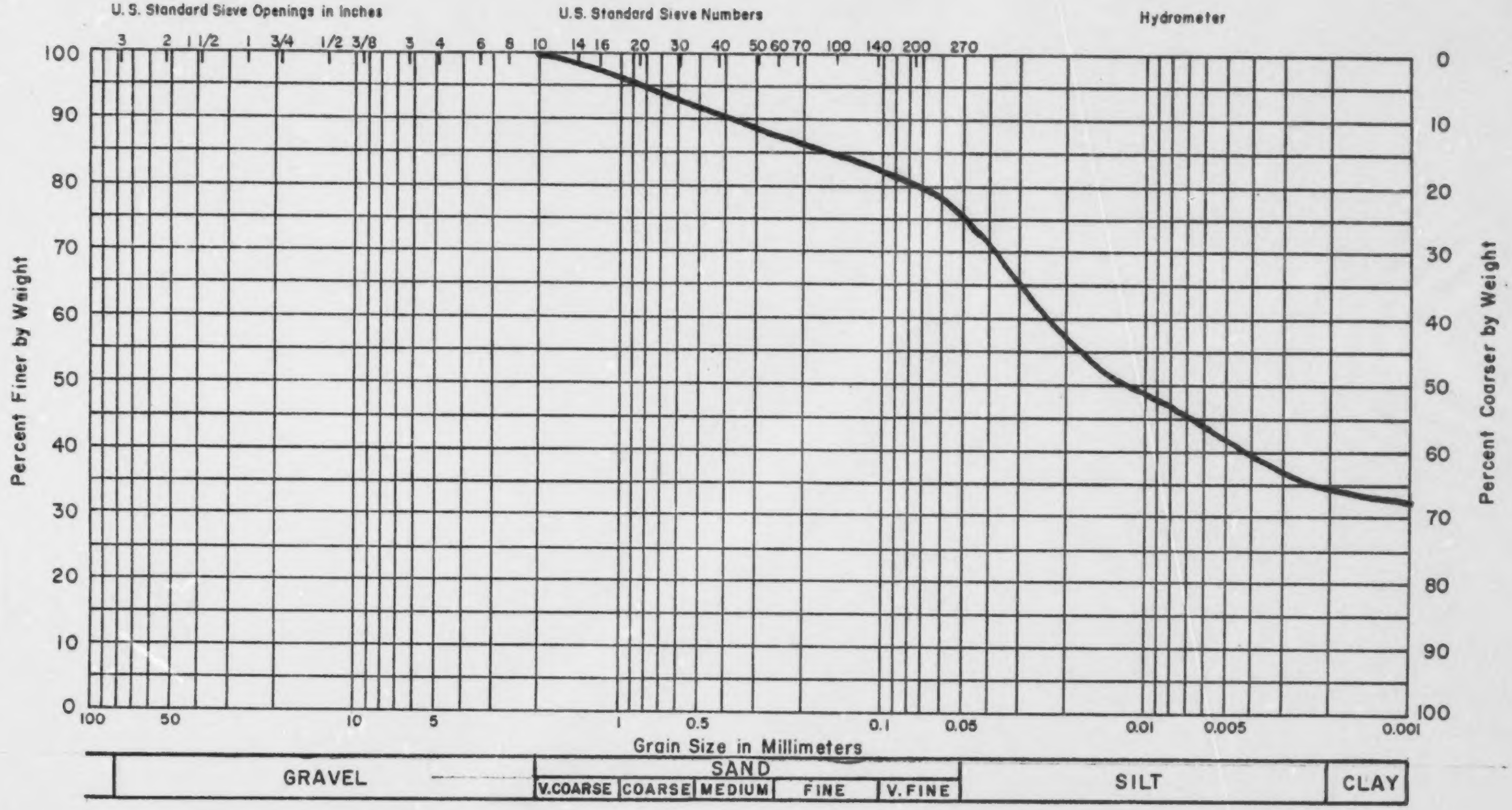
Figure 16 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
637	Las Virgenes	25	36	39	Clay Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

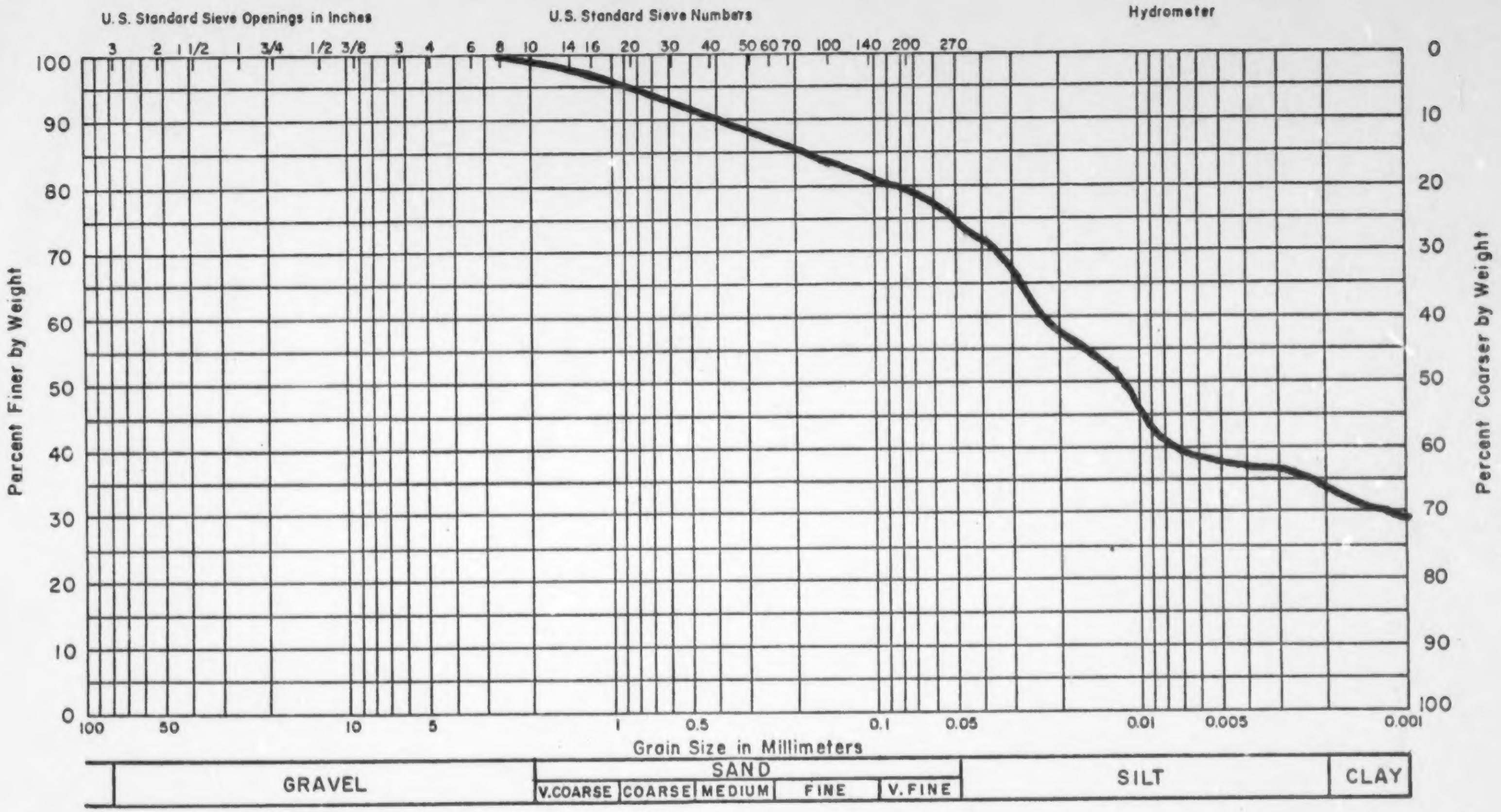
Figure 17 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
636	Las Virgenes	23	44	33	Clay Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

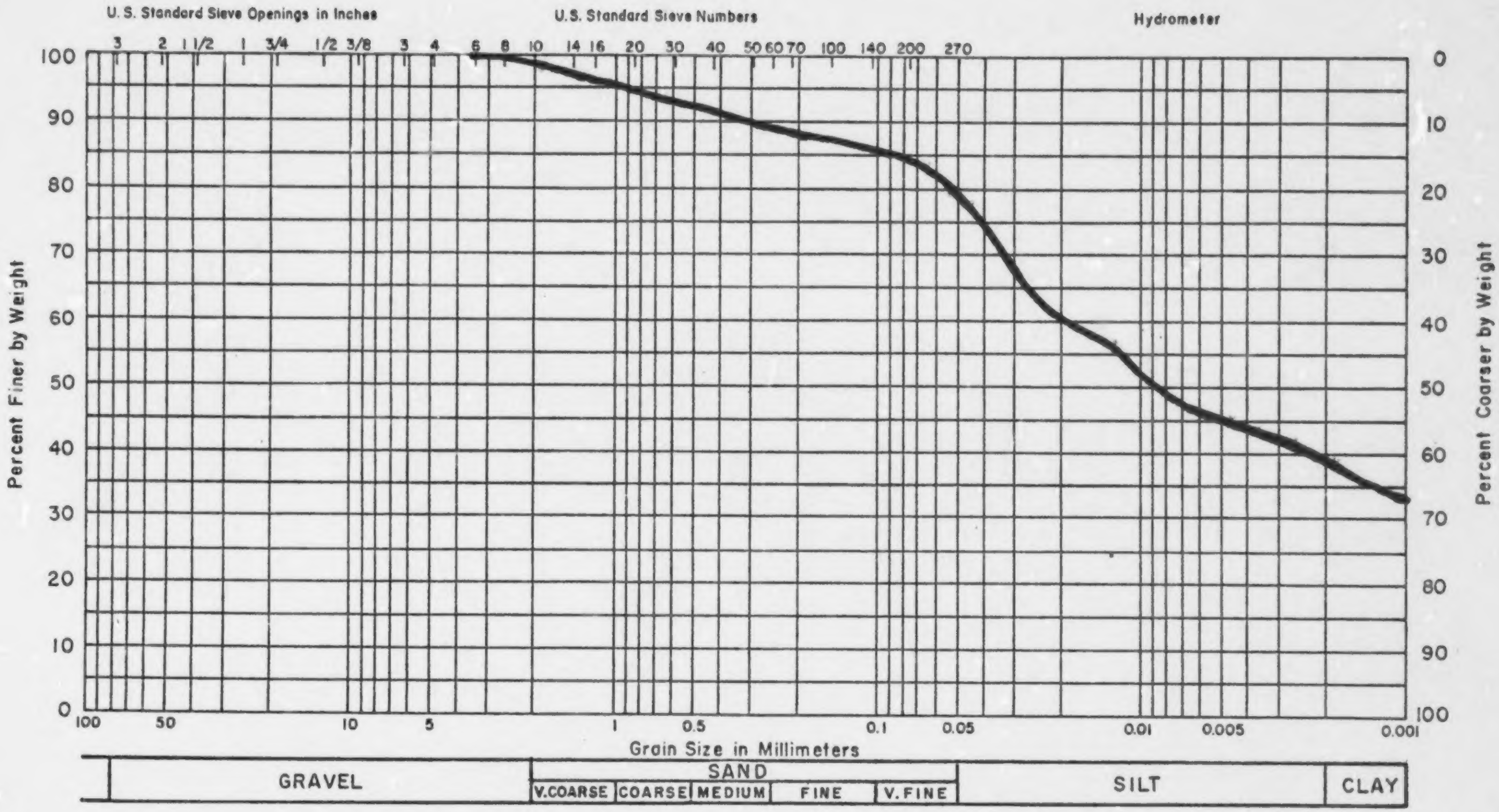
Figure 18 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
635	Las Virgenes Control Surface	26	39	35	Clay Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

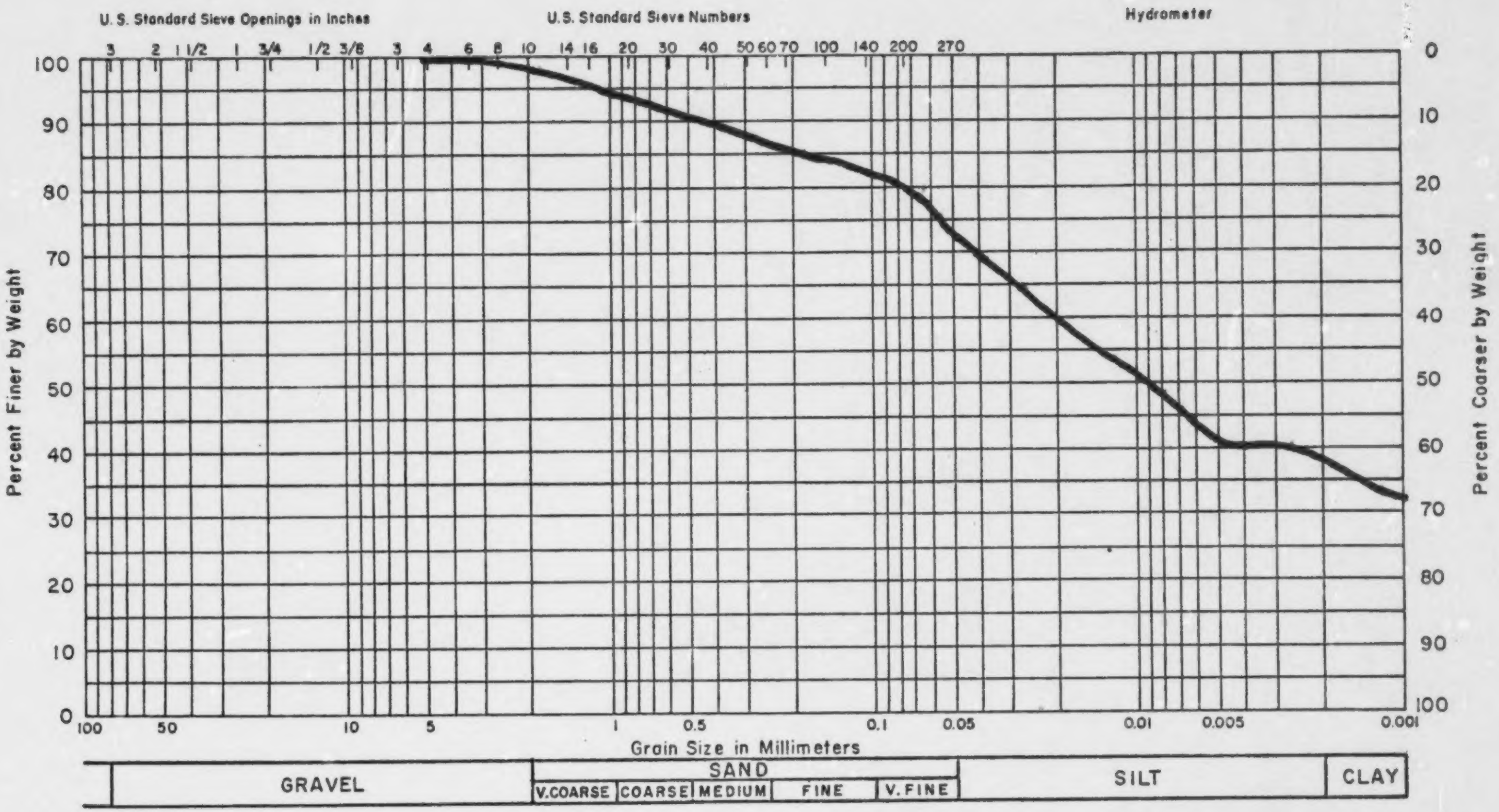
Figure 19 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
634	Las Virgenes	21	39	40	Clay Loam
	Control				
	31-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

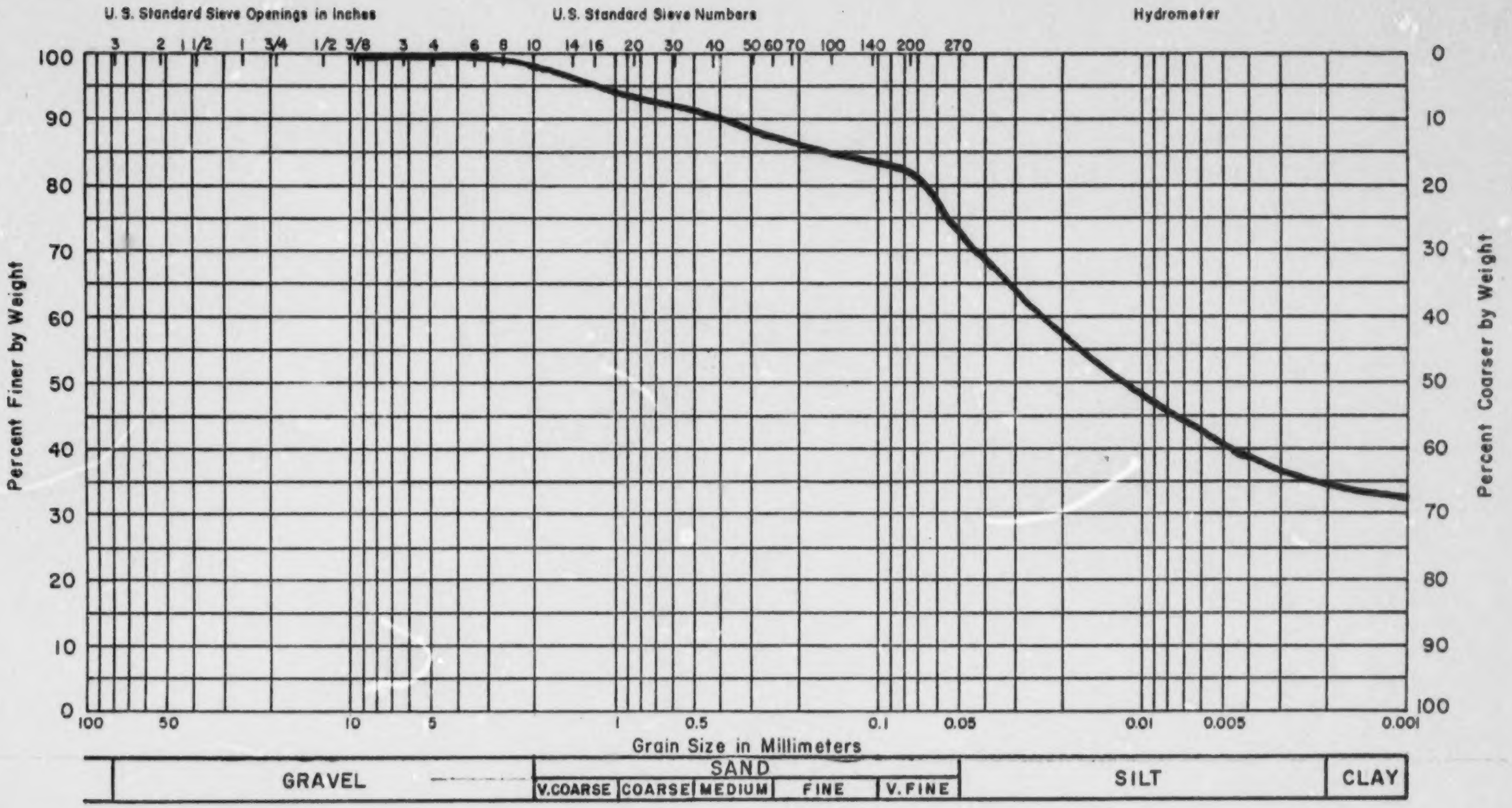
Figure 20 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
633	Las Virgenes	26	36	38	Clay Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 21 Las Virgenes, CA, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
632	Las Virgenes	27	36	37	Clay Loam
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 22 Las Virgenes, CA, Particle Size Analysis

TABLE 28

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

LAS VIRGENES, CALIFORNIA

	Treated Plot		Control Plot	
	.... µg/kg			Chlorinated Hydrocarbon
Soil				
Surface Composites	0.03		0.15	DDT
	0.2		<0.03[1]	DIELDRIN
	0.09		0.01	PCB 1221
	<0.01		0.28	PCB 1248
Plant				
Composites	0.28		<0.01	DDT
	0.8		<0.01	DIELDRIN
	<0.01		<0.4	PCB 1221
	<0.01		<0.5	PCB 1248
	(4/15/76)	(8/4/76)	Field Dried	
Stabilized Sludge	<0.25	<0.06	<0.07	DDT
	<0.3	<0.02	2.70	DIELDRIN
	<0.1	<0.1	< .07	PCB 1221
	3302	<6	1626	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 29

PARASITES IN SLUDGES, SOILS, AND PLANTS

LAS VIRGENES, CALIFORNIA

Sample Description	Results
Sludge	
Raw (4/15/76)	Negative
Raw (8/4/76)	Negative
Stabilized (4/15/76)	Negative
Stabilized (8/4/76)	Negative
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 30

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976 LAS VIRGENES, CALIFORNIA

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 4/15	11.9x10^{6}	$\geq$1.7	+	+	+	ND	+	-	-	9.3x10^{2}	+	+	+	8.0x10^{4}	+	+	+
Raw 8/4	2.15x10^{10}	ND	+	-	-	ND	+	-	-	ND	+	-	-	3.1x10^{8}	+	+	+
Stab 4/15	No sample																
Stab 8/4	3.33x10^{10}	ND	+	-	-	ND	+	-	-	2.7x10^{6}	+	+	+	2.7x10^{8}	+	+	+
Plants																	
Treated	8.93x10^{8}	ND	-	-	-	ND	+	-	-	ND	+	-	-	6.6x10^{2}	+	+	+
Control[2]	---	ND	+	-	-	ND	+	-	-	ND	-	-	-	1.5x10^{7}	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^{4}).
**Observations reported as + or -.
ND = none detected.

2 - An accurate total count on the plant control composite was not obtained due to excessive overgrowth of fungal contaminates.

TABLE 30 (continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
	(10^6)													(10^3)			
Soils - Treated Composites																	
Surface	66.3	ND	+	+	-	ND	+	+	-	11	+	+	+	54	+	+	+
30-61 cm	8.89	ND	+	-	-	ND	+	-	-	ND	+	-	-	5.3	+	+	+
61-91 cm	7.73	ND	+	-	-	ND	+	-	-	ND	+	-	-	5.2	+	+	+
91-122 cm	9.07	ND	+	-	-	ND	+	-	-	ND	+	-	-	.24	+	+	+
Soils - Control Composites																	
Surface	99.7	ND	+	-	-	ND	+	-	-	3.9	+	+	+	59	+	+	+
30-61 cm	21.1	ND	+	-	-	ND	+	-	-	3.5	+	+	+	.025	+	+	+
61-91 cm	7.06	ND	+	-	-	ND	+	-	-	ND	+	-	-	.25	+	+	+
91-122 cm	4.19	ND	+	-	-	ND	+	-	-	4.0	+	+	+	.13	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER III

WILMINGTON, OHIO

SITE DESCRIPTION

Location

This study site is located east of Wilmington, Ohio, approximately 72 km (45 mi) northeast of Cincinnati. Sludge generated by the Wilmington Wastewater Treatment Plant (STP) is spread on 22.7 ha (45 acre) of a 26.3 ha (65 acre) farm located 10 km (6 mi) southwest of the STP. Both the treated and control plots are located on this farm.

Physical Conditions

The study site is characterized by very gently rolling terrain (typically less than 4 percent grade) and is covered with pasture grasses, alfalfa, and red clover. Adjacent properties are in similar use.

Lake Cowan,abounding with a variety of species of game fish, is located approximately 0.5 km (0.3 mi) south of the test and control plots (see Figure 23), both of which slope in the direction of the lake. The slope of the treated plot is estimated to be approximately 2 percent, whereas the control plot, on slightly steeper terrain, has a slope of 2 to 4 percent.

As shown in Figure III-1, the two fields are adjacent. Both are 3.6 ha (9 acre) in size and the plots within are both approximately 69 x 46 m (225 x 150 ft) (see Figures 24 and 25). The field designated as control has been excluded

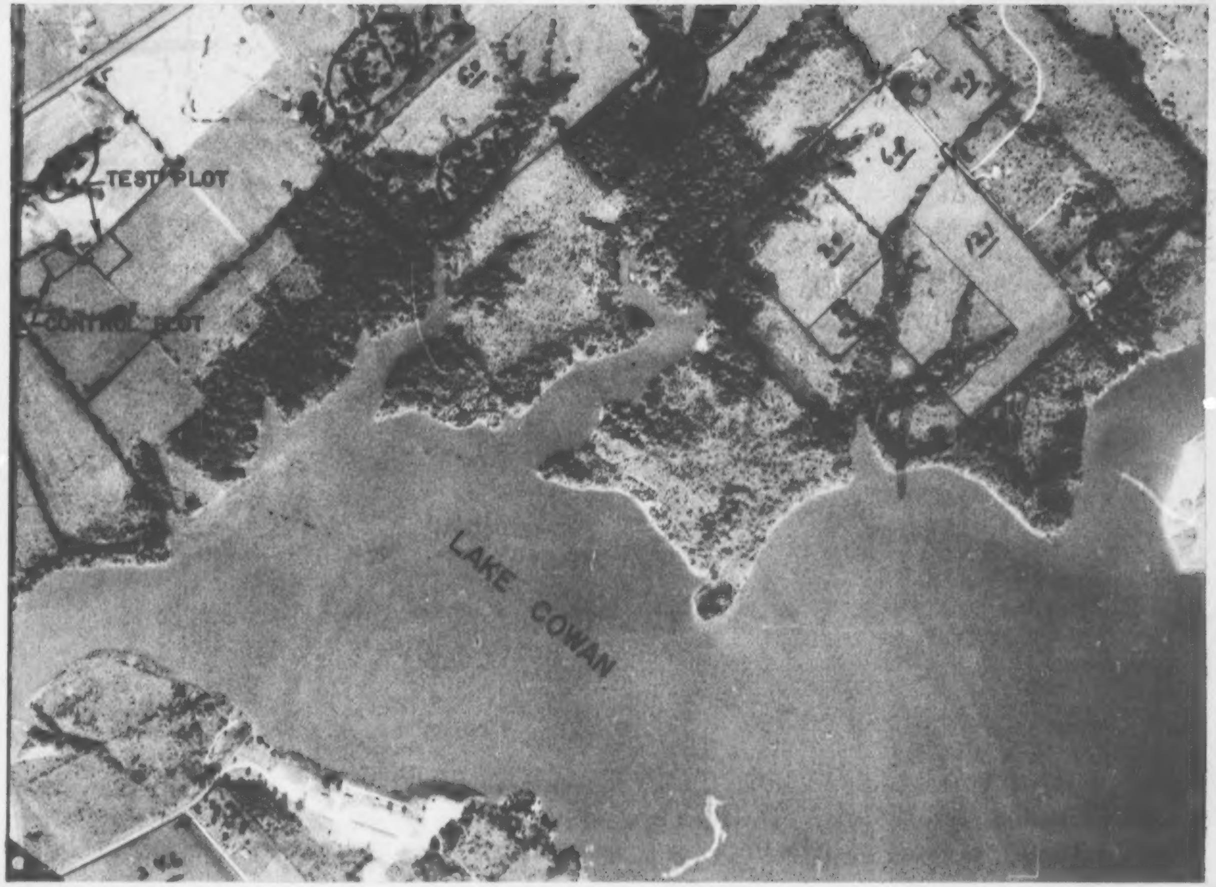

TEST PLOT
CONTROL PLOT
LAKE COWAN

Figure 23

Wilmington, Ohio

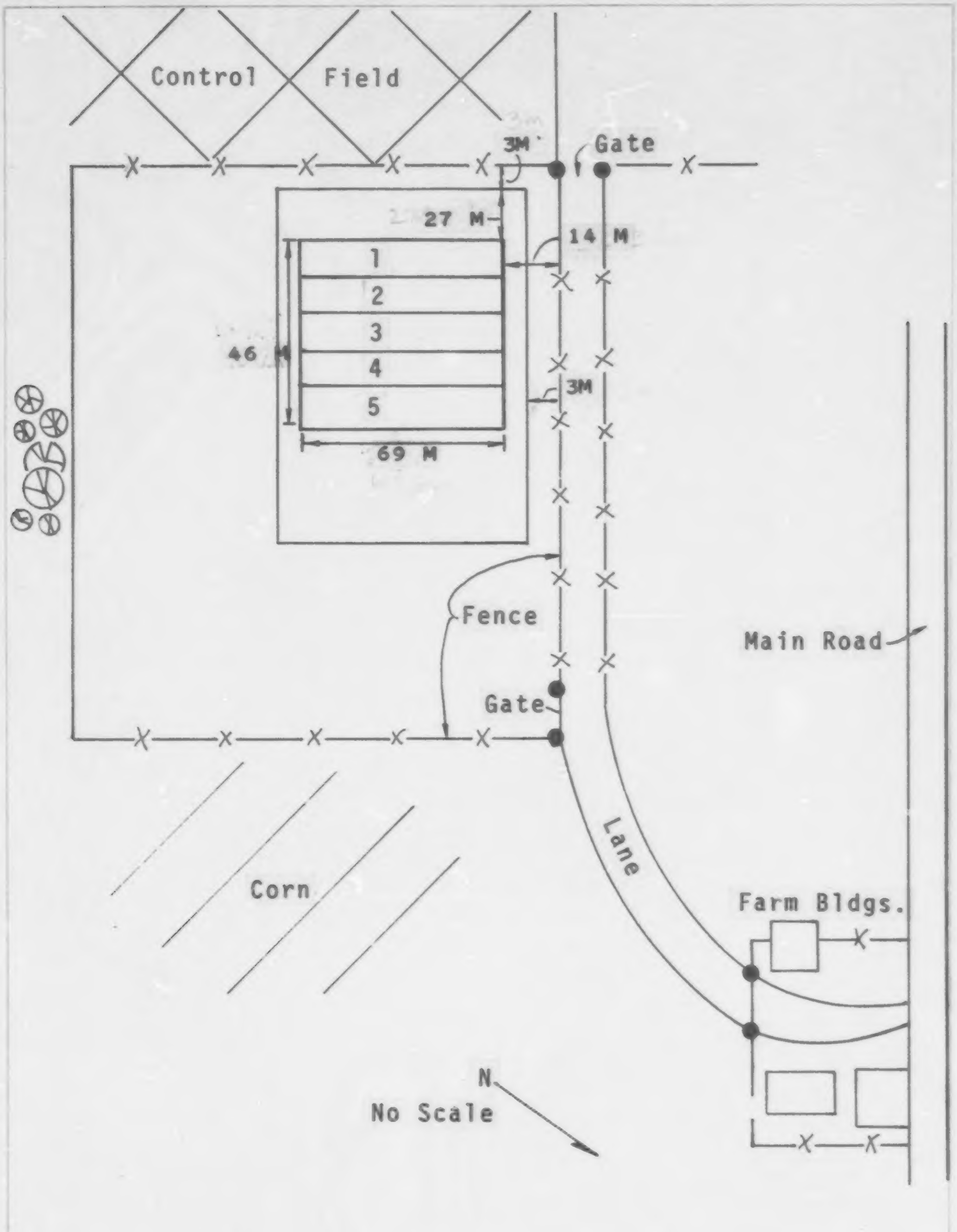

Control
Field
3M
Gate
27 M
14 M
1
2
3
4
5
46 M
3M
69 M
Fence
Main Road
Gate
Lane
Corn
Farm Bldgs.
N
No Scale

Figure 24 Wilmington Treated Plot

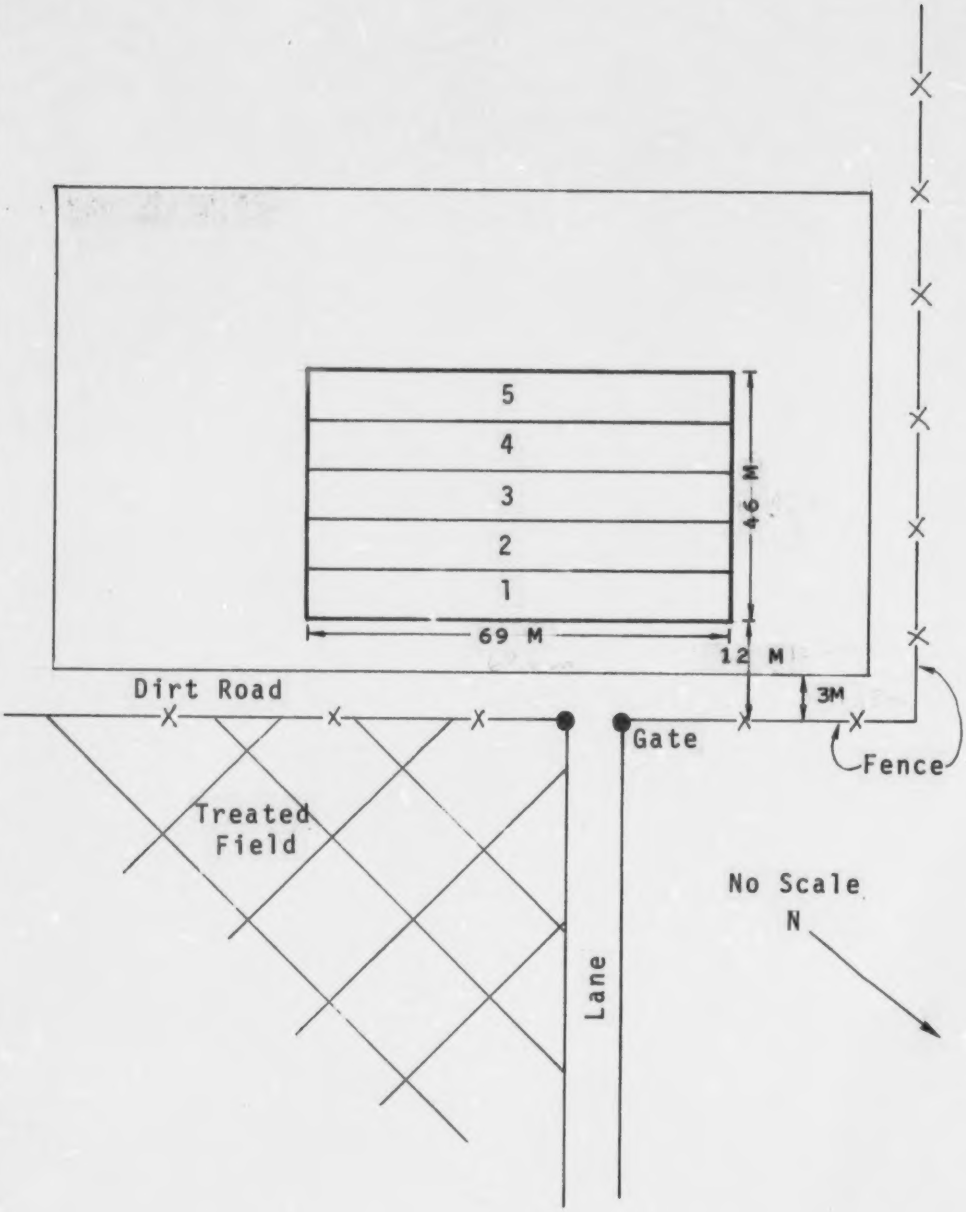

5
4
3
2
1
46 M
69 M
12 M
3M
Dirt Road
Gate
Fence
Treated Field
Lane
No Scale
N

Figure 25 Wilmington Control Plot

108

from sludge application principally due to its topography and location. This steeper sloped ground forms the western property boundary of the farm and as such, represents the greatest transport distance for a sludge truck. These factors (slope and distance) have been responsible for this field remaining in a non-amended state.

Groundwater at the site is at a depth of approximately 18.3 m (60 ft).

Farming Practices

Both the treated and control fields have been in a crop rotation pattern of corn, oats, and pasture grasses. The present crop on both fields is a mixture of grasses consisting of timothy grass (Phleum pratense), orchard grass (Dactylis glomerata), alfalfa (Medicago sativa), and red clover (Trifolium pratense).

The treated field was planted in corn in 1973 and 1974, oats in 1975, and to the above mentioned grasses in 1976. The grasses will remain until 1981, at which time the field will be planted to corn. The control field, in the same rotation as the treated, will remain in grasses until 1977.

At the time of sampling, the treated and control sites had uniform, lush stands of mixed grasses ranging in height from 23 to 76 cm (9 to 30 in). Alfalfa was sampled for this study, since it was common to both fields and growth in both fields appeared similar.

Of the total 26.3 ha (65 acre), 22.7 ha (56 acre) have a history of sludge spreading dating back to 1959. Records of sludge distribution, however, were not maintained prior to 1968. In addition, records were not available on a field-by-field distribution basis. Estimates were, therefore, made by the farmer to determine the sludge application rates. Assuming that the treated field in which the sampled plot was located received one uniform coating of sludge per year and that sludge solids have averaged 5 percent (STP data), the annual application rate has been 6.8 dry m tons/ha (3 dry tons/acre). The farmer estimated that this application rate has been reasonably consistent since 1959.

Normal harvest patterns result in two cuttings annually, the first in June and the second in September. The June and September, 1976, cuttings yielded a total of approximately 650 bales from the treated field and 690 bales from the control field. These grass crops are used for beef production. The farmer reported no adverse health effects to his cattle.

Fertilizer, Agrico 12-12-12, was applied to the treated area during June, 1974 at 336 kg/ha (300 lbs/acre). No fertilizers have been used in the control field since 1971. Atrazine has been used in the past on both fields when they were in corn. Neither field has received lime for the last 10 years.

CLIMATE

The climate of the Wilmington area is continental with a rather wide range of temperatures from winter to summer. Maximum precipitation occurs during winter and spring, with a minimum during late summer and fall. The heaviest snowfalls usually occur during January, although the heaviest recorded 24-hour amounts have occurred during late November and February.

Summers are warm and humid. The temperature reaches 32°C (90°F) or higher about 26 days each year. Winters are moderately cold with frequent periods of overcast.

The freeze-free period averages 187 days annually, from mid-April to the latter part of October. Additional meteorological data are presented in Table 31.

SOIL DESCRIPTION

General Soil Type

Clinton County lies entirely in the glaciated region of Ohio. The northeastern three-fourths is covered by medium-textured drift of Wisconsin age which is more naturally fertile than other parts of the county. The remainder is covered by the much older, deeply leached drift of Illinoian age. The Illinoian till plane is known locally as the Pine-Oak Flats.

The treated and control plots have two basic soil series, Fincastle and Xenia. The Xenia series is predominant and common to both sites. Runoff from the Xenia soil is slow to rapid. The risk of erosion is moderate to high, depending on steepness, length of slopes, and the type of vegetation. Most Xenia soil is slightly or moderately eroded, with a deep root zone, a medium moisture-supplying capacity, and a surface soil medium in organic matter. In the severely eroded soil, these properties are less favorable for agriculture.

The Xenia series consists of light-colored, moderately well drained, nearly level to sloping soils on uplands. The

TABLE 31

WILMINGTON, OHIO

Meteorological Data For The Current Year

Station: GREATER CINCINNATI AIRPORT BOONE COUNTY, KENTUCKY Standard time used: EASTERN Latitude: 39° 03' N Longitude: 84° 40' W Elevation (ground): 869 feet Year 1975

Month	Temperature °F: Averages: Daily maximum	Temperature °F: Averages: Daily minimum	Temperature °F: Averages: Monthly	Temperature °F: Extremes: Highest	Temperature °F: Extremes: Date	Temperature °F: Extremes: Lowest	Temperature °F: Extremes: Date	Degree days Base 65 °F: Heating	Degree days Base 65 °F: Cooling	Precipitation in inches: Water equivalent: Total	Precipitation in inches: Water equivalent: Greatest in 24 hrs.	Precipitation in inches: Water equivalent: Date	Precipitation in inches: Snow, Ice pellets: Total	Precipitation in inches: Snow, Ice pellets: Greatest in 24 hrs.	Precipitation in inches: Snow, Ice pellets: Date	Relative humidity, pct.: Hour 01 (Local time)	Relative humidity, pct.: Hour 07 (Local time)	Relative humidity, pct.: Hour 13 (Local time)	Relative humidity, pct.: Hour 19 (Local time)	Wind: Resultant: Direction	Wind: Resultant: Speed m.p.h.	Wind: Average speed m.p.h.	Wind: Fastest mile: Speed m.p.h.	Wind: Fastest mile: Direction	Wind: Fastest mile: Date	Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days: Sunrise to sunset: Clear	Number of days: Sunrise to sunset: Partly cloudy	Number of days: Sunrise to sunset: Cloudy	Number of days: Precipitation .01 inch or more	Number of days: Snow, Ice pellets 1.0 inch or more	Number of days: Thunderstorms	Number of days: Heavy fog, visibility ¼ mile or less	Number of days: Temperature °F: Maximum: (b) 90° and above	Number of days: Temperature °F: Maximum: 32° and below	Number of days: Temperature °F: Minimum: 32° and below	Number of days: Temperature °F: Minimum: 0° and below	Average station pressure mb: Elev. 877 feet m.s.l.
JAN	41.9	26.0	34.0	67	29	6	13	953	0	4.05	1.59	10-11	2.0	0.7	19	79	85	76	76	23	4.7	10.5	30	22	10		7.9	2	8	21	16	0	2	3	0	4	23	0	986.5
FEB	44.9	29.2	37.1	65	22	7	10	774	0	3.38	2.13	22-23	2.2	1.1	24-25	73	75	67	66	24	2.9	10.7	28	27	25		8.0	4	3	21	16	0	3	2	0	3	18	0	984.8
MAR	48.9	30.6	39.8	74	21	14	9	778	0	6.76	1.60	23-24	6.8	3.9	10	75	79	63	63	26	2.2	10.8	35	23	24		7.8	3	6	22	14	2	7	4	0	1	17	0	983.1
APR	61.1	40.0	50.6	79	29	25	5	435	8	4.16	2.15	23-24	0.2	0.2	3	64	68	47	51	30	1.4	10.1	32	26	19		6.1	7	9	14	12	0	6	1	0	0	8	0	985.8
MAY	78.9	56.3	67.6	92	24	41	2	50	138	3.11	1.25	31	0.0	0.0		74	79	51	54	24	1.3	7.5	29	35	6		6.8	5	12	14	9	0	6	2	3	0	0	0	983.1
JUN	82.7	61.8	72.3	94	20	51	8	10	236	5.09	1.74	5	0.0	0.0		83	85	60	63	22	3.1	8.3	26	21	17		6.0	8	11	11	12	0	9	3	6	0	0	0	985.1
JUL	86.8	62.3	74.6	92	31	48	14	5	309	1.62	0.35	24	0.0	0.0		86	88	52	59	22	1.7	6.4	25	27	19		4.9	13	11	7	10	0	8	2	10	0	0	0	985.1
AUG	87.5	66.2	76.9	94	13	56	8	0	376	1.97	0.92	15	0.0	0.0		89	93	59	70	23	2.9	7.0	23	36	11		6.5	5	11	15	12	0	11	1	13	0	0	0	987.1
SEP	72.7	52.1	62.4	92	5	39	28	142	72	3.64	1.92	11-12	0.0	0.0		90	96	62	75	32	0.3	7.2	32	24	5		6.6	7	8	15	11	0	3	3	3	0	0	0	987.8
OCT	68.5	46.5	57.5	87	13	30	3	244	19	4.59	2.25	17-18	0.0	0.0		78	85	58	68	22	1.7	7.8	25	05	17		5.7	11	7	13	8	0	0	2	0	0	1	0	988.2
NOV	59.6	38.5	49.1	80	5	23	28	474	3	2.50	0.82	9-10	3.7	3.0	26	74	81	62	71	22	5.6	9.1	26	18	30		6.3	9	4	17	10	1	2	0	0	0	9	0	987.5
DEC	45.2	29.5	37.4	69	14	11	18	848	0	3.36	0.94	14-15	1.7	0.8	27	73	73	66	70	24	3.1	9.3	26	22	15		7.8	4	7	20	12	0	0	2	0	1	23	0	988.2
YEAR	64.9	44.9	54.9	94	AUG 13	6	JAN 13	4713	1161	44.23	2.25	OCT 17-18	16.6	3.9	MAR 10	78	82	60	66	23	2.4	8.7	35	23	MAR 24		6.7	78	97	190	142	3	57	25	35	9	99	0	986.0

TABLE 31 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F	
	Normal			Extremes					
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling
(a)				14		14			
J	39.7	22.4	31.1	69	1967	-19	1963	1051	0
F	42.7	23.8	33.3	73	1972	-10	1965	888	0
M	51.8	31.6	41.7	80	1974	9	1970	722	0
A	65.0	42.7	53.9	87	1962	17	1964	341	8
M	74.4	51.9	63.2	93	1962	27	1963	138	82
J	83.2	61.0	72.1	97	1971	39	1972	9	222
J	86.5	64.6	75.6	100	1970	47	1963	0	329
A	85.8	63.0	74.4	102	1962	43	1965	0	294
S	79.7	55.9	67.8	98	1964	33	1963	44	128
O	68.5	45.0	56.8	88	1963	16	1962	271	17
N	53.2	34.3	43.8	80	1975	6	1964	636	0
D	42.0	25.3	33.7	70	1970	-11	1963	970	0
YR	64.4	43.5	54.0	102	AUG 1962	-19	JAN 1963	5070	1080

Month	Precipitation in inches										
	Water equivalent							Snow, Ice pellets			
	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)		28		28		28		28		28	
J	3.34	9.43	1950	0.75	1967	4.33	1959	15.3	1964	7.6	1964
F	3.04	6.72	1955	0.61	1958	2.32	1950	13.3	1971	9.3	1966
M	4.09	12.18	1964	1.14	1960	5.21	1964	13.0	1968	9.8	1968
A	3.64	7.19	1970	1.04	1971	2.72	1950	3.3	1953	3.3	1953
M	3.74	9.48	1968	1.13	1964	3.71	1956	T	1966	T	1966
J	3.81	6.27	1973	0.95	1965	3.45	1974	0.0		0.0	
J	4.12	8.36	1962	1.18	1951	3.47	1953	0.0		0.0	
A	2.62	6.10	1954	0.31	1953	3.12	1957	0.0		0.0	
S	2.55	8.25	1950	0.18	1963	3.30	1950	0.0		0.0	
O	2.15	4.59	1975	0.25	1963	2.47	1973	1.7	1962	1.7	1962
N	3.08	6.26	1972	0.43	1949	3.36	1948	12.1	1966	9.0	1966
D	2.86	6.17	1951	0.58	1955	2.96	1948	12.5	1960	6.0	1974
YR	39.04	12.18	MAR 1964	0.18	SEP 1963	5.21	MAR 1964	15.3	JAN 1964	9.8	MAR 1968

Month	Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset
	Hour 01	Hour 07	Hour 13	Hour 19	Mean speed m.p.h.	Prevailing direction	Fastest mile				
	(Local time)						Speed m.p.h.	Direction	Year		
(a)	13	13	13	13	28	16	12	12			24
J	75	78	66	69	10.7	SSW	40	27	1971		7.5
F	73	77	63	64	10.7	SSW	40	29	1967		7.3
M	73	78	61	62	11.2	SSW	37	23	1964		7.5
A	71	76	54	55	10.9	SSW	40	25	1970		7.1
M	75	78	53	56	8.9	SSW	35	31	1973		6.7
J	80	81	55	58	7.9	SSW	40	24	1971		6.2
J	82	84	56	60	7.1	SSW	35	32	1966		6.1
A	83	88	56	62	6.7	SSW	32	07	1973		5.7
S	83	88	58	68	7.4	SSW	32	24	1975		5.7
O	77	83	54	64	8.0	SSW	35	27	1967		5.4
N	75	79	63	69	9.6	SSW	35	20	1968		7.1
D	77	79	69	72	10.1	SSW	40	21	1973		7.6
YR	77	81	59	63	9.1	SSW	40	21	DEC 1973		6.7

Month	Mean number of days											Average station pressure mb.
	Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F				
								Max.		Min.		
	Clear	Partly cloudy	Cloudy					(b) 90° and above	32° and below	32° and below	0° and below	Elev. 877 feet m.s.l.
(a)	24	24	24	28	28	28	12	13	13	13	13	3
J	5	6	20	12	2	1	3	0	11	25	3	987.4
F	5	6	17	11	2	1	2	0	7	24	2	985.7
M	5	6	20	13	2	3	2	0	1	16	0	983.1
A	5	8	17	13	*	4	1	0	0	5	0	984.2
M	6	9	16	12	0	6	1	1	0	*	0	982.3
J	6	11	13	11	0	7	1	5	0	0	0	984.0
J	7	12	12	10	0	9	2	7	0	0	0	985.4
A	8	13	10	9	0	8	3	6	0	0	0	986.9
S	9	9	12	8	0	3	4	2	0	0	0	987.3
O	12	6	13	8	*	1	3	0	0	3	0	989.1
N	6	6	18	11	1	1	2	0	1	13	0	987.0
D	5	6	20	12	1	*	3	0	6	21	*	986.4
YR	79	98	188	129	7	44	26	21	26	107	5	985.7

soils have developed in 46 to 102 cm (18 to 40 in) of loess overlying medium-textured, calcareous till of the Wisconsin age. Carbonates occur at a depth of 76 to 122 cm (30 to 48 in). The native vegetation consists of ash, elm, maple, and other deciduous trees.

A representative profile of Xenia silt loam as mapped in the Clinton County Survey, September, 1962, is described as follows:

- 0 to 20.3 cm (0 to 8 in) - dark grayish brown, friable silt loam; moderate, medium and fine, granular structure; medium acidity.
- 20.3 to 27.9 cm (8 to 11 in) - dark yellowish brown, friable silty clay loam; weak, fine, subangular blocky structure; strongly acidic.
- 27.9 to 48.3 cm (11 to 19 in) - dark brown to yellowish-brown, firm silty clay loam; moderate, fine to medium, subangular blocky structure, strongly acidic.
- 48.3 to 61 cm (19 to 24 in) - yellowish-brown, firm silty clay loam; many medium to fine distinct mottles of brown to grayish-brown; moderate, medium to coarse, subangular blocky structure; medium acidity.
- 61 to 86.4 cm (24 to 34 in) - yellowish-brown, friable clay loam; many fine, faint mottles of brown and dark yellowish-brown; weak, medium, subangular blocky structure to massive; medium acidity in upper part, gradually changing to neutral or alkaline in lower part.

- 86.4 to 122 cm (34 to 48 in) - mottled yellowish-brown to grayish-brown loam till; massive (structureless); calcareous.

The Fincastle soils are associated with the very poorly drained Brookstone, the moderately well drained Xenia, and the well drained Russell soils.

The texture of underlying till ranges from loam to silt loam. It is seldom leached of carbonates where the overlying loess is 91.4 cm (36 in) or more in thickness. In contrast, carbonates may be leached to a depth of 122 cm (48 in) where the overlying loess is less than 91.4 cm (36 in) thick. On the terminal moraine, carbonates may be as deep as 183 cm (72 in) from the surface. This extreme variation can occur in short horizontal distances.

Runoff from Fincastle soils is slow to medium in nearly level areas and medium on gentle slopes. These soils have moderately deep root zones, a medium moisture supplying capacity, and a surface soil that is medium in organic matter.

A representative profile of Fincastle silt loam as mapped in the September, 1962, Clinton County Soil Survey is described as follows:

- 0 to 20.3 cm (0 to 8 in) - dark grayish brown, friable silt loam; moderate, fine, granular structure; medium to slightly acidic.
- 20.3 to 35.6 cm (8 to 14 in) - yellowish brown, firm silt loam; many medium to fine distinct mottles of

brown and grayish brown; medium, subangular, blocky structure; medium acidity.

- 35.6 to 91.4 cm (14 to 36 in) - brown and dark yellowish brown, firm silty clay loam; medium, distinct yellow brown mottles; moderate, medium subangular blocky structure; medium to slightly acidic in upper part, grading to neutral in lower part; small weathered pebbles of glacial till in lower part.
- 91.4 to 122 cm (36 to 48 in) - many light brownish gray and dark yellowish brown mottles, friable loam till; massive in place; calcareous.

Treated Plot

The treated plot is characterized by soils of both series - Xenia (XeB1) and Fincastle (FnA1). However, sections 4 and 5 as shown in Figure 24 were the only two sections to contain the FnA1 soil. The observed sampling to 122 cm (48 in) followed the profiles of each soil series as described above.

Control Plot

The control field contains soil of the Xenia series - XeC1 and XeC2. The two types differ only in slope, the XeC2 being characteristic of the more severely sloped terrain. The sampled plot was staked out to avoid the XeC2 soil type. Samplings to 122 cm (48 in) were observed to follow the Xenia profile as described above.

Texture, pH, and other soil data of the treated and control plots are shown in Table 32.

TABLE 32

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

WILMINGTON , OHIO

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N (2)	PH (1)	CEC
			SAND	SILT	CLAY					
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	20.9	1.60	13	73	19	0.040	3.11	0.0	6.5	30
18-30 CM	17.6	0.64	9	64	27	0.013	3.70	2.70	6.6	30
30-61 CM	16.8	0.44	9	59	32	0.008	0.90	0.60	6.4	30
61-91 CM	15.4	0.24	12	58	30	0.006	0.60	1.08	6.9	30
91-122 CM	16.2	0.18	21	47	32	0.011	3.00	0.27	7.6	6
CONTROL										
SURFACE	19.7	1.61	10	76	14	0.052	3.50	4.80	6.6	30
18-30 CM	16.7	0.69	13	62	25	0.007	2.40	1.80	6.4	30
30-61 CM	16.3	0.53	9	61	30	0.005	4.40	1.60	6.6	30
61-91 CM	17.0	0.37	10	63	27	0.007	1.90	1.16	6.8	30
91-122 CM	16.4	0.22	20	55	25	0.0003	2.70	1.11	7.6	30

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The STP currently (1976) serves an actual population of 10,000 and a population equivalent of 19,000. When the plant was constructed in 1936, treatment consisted of grit removal and primary settling with discharge to Lydall Creek. In 1953, the STP was upgraded to secondary treatment with construction of secondary aeration tanks, a secondary clarifier, and an anaerobic sludge digester. In 1963, the plant was further improved by increasing the capacity from 3,800 cu m/day (1 mgd) to a present capacity of 7,600 cu m/day (2 mgd). The superintendent (also the farmer of both the treated and control sites) estimates that there is a sizable but unknown flow resulting from infiltration.

The STP utilizes a conventional activated sludge process. Influent to the plant is comminuted, passed through a grit removal system, preaerated for about 20 minutes, and settled in three primary settling tanks. Primary effluent then enters sludge aeration tanks with an average detention time of approximately six hours. The mixed liquor is settled in secondary clarifiers for about two hours. Secondary effluent is given contact chlorination prior to discharge to Lydall Creek. No chemicals or additives other than chlorine are used. Table 33 presents treatment efficiencies for calendar 1975.

An estimated 25 percent of the flow to the STP originates from industrial sources. The major contributors are:

TABLE 33

WILMINGTON, OHIO - SECONDARY EFFLUENT TREATMENT EFFICIENCIES

Month	Influent		Effluent		% Reduction	
	BOD (mg/l)	SS (mg/l)	BOD (mg/l)	SS (mg/l)	BOD	SS
Jan.	130	274	15	42	88.5	84.7
Feb.	106	340	14	46	86.8	86.5
Mar.	107	220	16	33	85.0	85.0
Apr.	160	314	12	28	92.5	91.1
May	183	342	9	16	95.1	95.3
June	217	347	18	33	91.7	90.5
July	228	338	10	15	95.6	95.6
Aug.	245	285	14	21	94.3	92.6
Sept.	269	370	16	16	94.1	95.7
Oct.	240	549	16	19	93.3	96.5
Nov.	275	680	15	28	94.5	95.9
Dec.	184	600	16	30	91.3	95.0
Average	195	388	14	27	92.7	93.0

Industry	Product
Randall Company	Metal products
Cincinnati Millacron	Milling tools
Erwing Auger Bit	Machined tools
International Paper	Paper products
Lee Decks	Electrical switches
Comptrol	Hydraulic valves

Individual flow, waste strength, or heavy metal contributions by the various industries is unknown. However, the Randall Company, a subcontractor to Ford Motors, supplies tail pipes and door trim utilizing a zinc dipping process. This company is required to pretreat their effluent, but the effectiveness of pretreatment is unknown.

Sludge Stabilization and Storage

The STP utilizes two-stage anaerobic digestion. Sludge from the secondary clarifiers is returned to both the primary clarifiers and the aeration tanks. Combined sludge is pumped from the primary clarifiers into a 379 cu m (0.1 MG) primary digester having a retention time of approximately 10 days. Supernatant is returned to the primary clarifiers. The partially stabilized sludge is pumped to a 834 cu m (8.22 MG) secondary digester which provides an additional 20 days retention time. Sludge, as needed, is withdrawn from the secondary digester for landspreading purposes.

Approximately 95 percent of the digested sludge is landspread without dewatering. The remaining five percent is bed-dried in one of 8 drying beds. Each bed is 12 x 24 x 0.5 m

(40 x 80 x 1.5 ft). The dried sludge is offered to the community as a soil conditioner on a first-come, first-served basis. In addition, the beds offer extra storage capacity to the STP during inclement weather.

On September 26, 1975, a Phase I grab sample of stabilized sludge from the secondary digester was obtained, the chemical analysis results of which are presented in Table 34. The Pb and Zn concentrations appeared to be very high. No other sludge analytical data exists.

Disposal of Sewage Sludge

Table 35 presents monthly sludge distribution records from 1968 to the present.

The STP (based on 1968 to 1975 data) generates 1,627 cu m (0.43 MG) of sludge annually. Assuming an average solids content of five percent, the STP generates an annual average of 81 dry m tons (90 dry tons).

Sludge spreading is accomplished via a 3.8 cu m (1,000 gal) tank truck. The tank has been modified by the addition of a 61 cm (24 in) length of 10 cm (4 in) diameter pipe fitted to the valve on the tank; the other end is welded to a rectangular baffle plate (refer to Photo 15). The valve on the rear of the tank truck controls the rate of sludge discharging onto the baffle plate. The baffle design spreads sludge over an area approximately 1.2 m (4 ft) wide as the truck is driven across the field. Each load is normally emptied over a path covering approximately 230 m (750 linear ft).

TABLE 34

WILMINGTON, OHIO - STABILIZED LIQUID SLUDGE ANALYSIS[1]

Parameter	Concentrations[2]
	- μg/g -
Cd	15
Cu	394
Ni	35
Zn	49,700
Pb	8,670
Moisture (%)	94.6

---

[1] Phase I stabilized sludge sample, September 26, 1975.

[2] Data expressed on an oven dry weight basis.

TABLE 35

WILMINGTON, OHIO - LIQUID SLUDGE HAULING (cu m)

Month	1968	1969	1970	1971	1972	1973	1974	1975
Jan.	182	110	140	140	95	19	83	0
Feb.	329	64	95	76	91	120	238	0
Mar.	144	72	132	83	114	135	167	0
Apr.	178	95	132	0	126	0	250	0
May	212	102	170	159	125	159	132	125
June	182	197	231	155	159	106	120	76
July	167	197	326	204	231	106	167	121
Aug.	269	95	242	288	120	148	87	178
Sept.	276	185	246	95	0	185	114	254
Oct.	163	178	106	114	0	204	114	326
Nov.	102	98	136	151	0	91	76	322
Dec.	79	121	121	132	0	76	76	114
Totals	2,283	1,514	2,077	1,597	1,071	1,347	1,624	1,516

The majority of sludge hauling is typically accomplished during late spring and early summer. This is the only time during the year which permits the tank truck on the field without serious soil compaction or crop damage. Other areas of the study site are more conducive to sludge spreading on a year-round basis.

Interviews with the STP personnel indicate no apparent aesthetic or environmental problems associated with the current method of sludge disposal.

Photographs 11 through 15 show respectively the treated field, control field, drying beds, the truck used for sludge spreading, and a close-up of the pipe extension-baffle plate modification to the tank truck.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

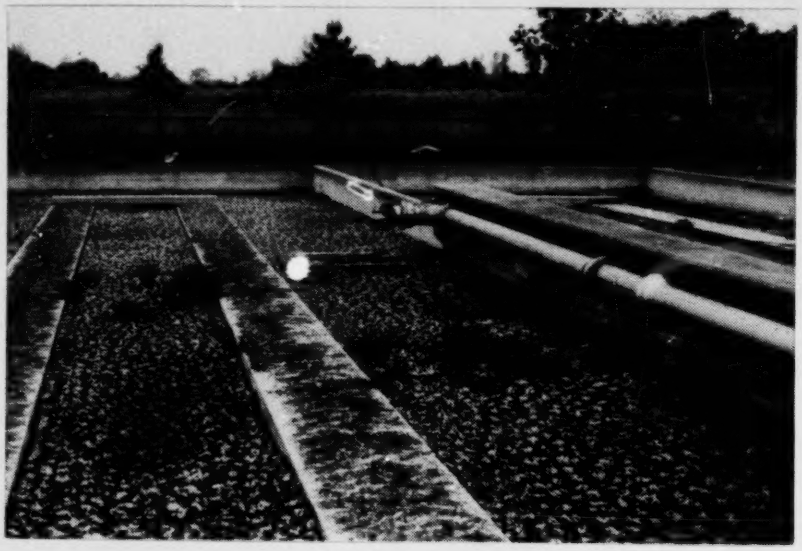
Interviews were conducted with the Public Water Department of Wilmington, the Clinton County Public Health Department, the Ohio State Public Health Service, the local Soil Conservation Service, and the Wilmington News Journal. A review of comments collected from these interviews revealed little public knowledge of sludge utilization practices in the Wilmington area. When questioned concerning the public reaction to the current practices, the common reply was that there was little public knowledge of the practice. No articles, favorable or unfavorable, have ever appeared in the local Wilmington newspaper.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

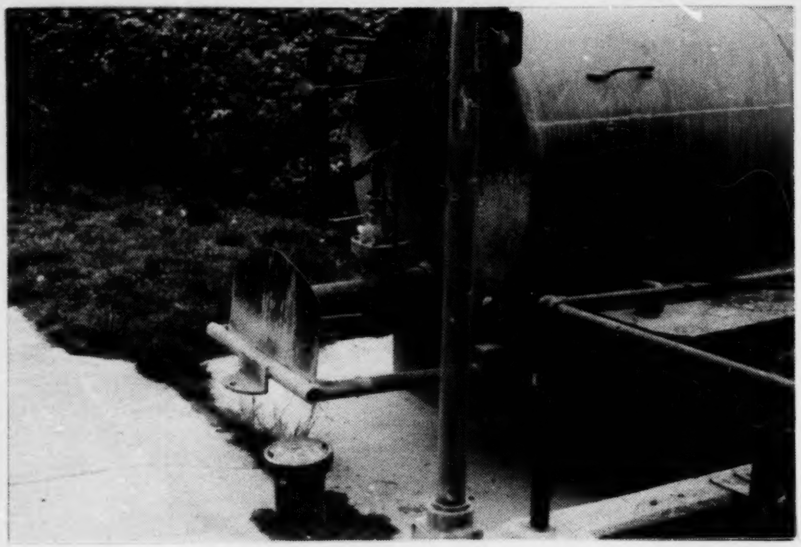
There are currently no city, county, or state regulations which affect the spreading practices at the Wilmington site.

Photograph 11
Treated Field

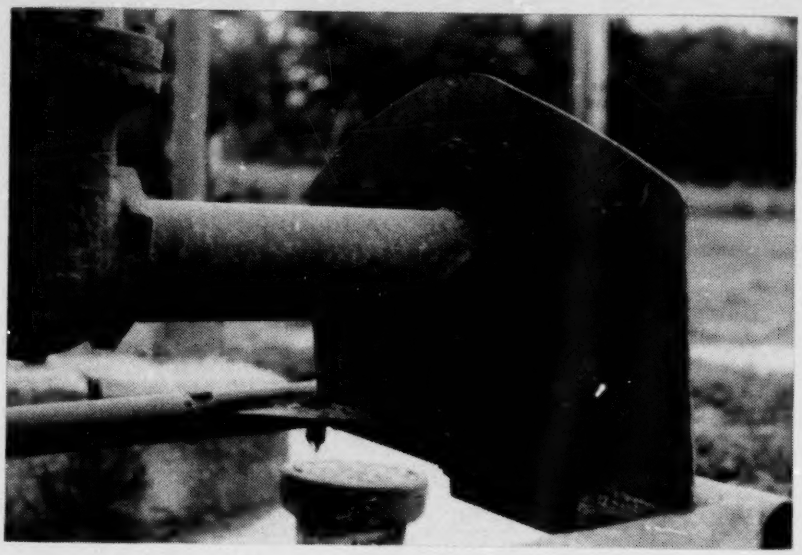
Photograph 12
Control Field



Photograph 13
Drying Beds



Photograph 14
Sludge Spreading Tank



Photograph 15
Close-up, Baffle Arrangement

The Cooperative Extension Service of Ohio State University, however, in conjunction with the Ohio Agricultural Research and Development Center has issued Bulletin #598 entitled Ohio Guide for Land Application of Sewage Sludge. On Page 12 of this bulletin, under the heading of RELATIONSHIP AMONG AGENCIES, the bulletin describes the authority of the Ohio Environmental Protection Agency to regulate land application of sewage sludge ...from both state and federal laws:

> "Sections 6111.44 and 6111.46 of the Ohio Revised Code require that plans for all sewage treatment systems be submitted to OEPA for approval. Approval will be based on whether or not the proposed system will pollute the state's waters, present a hazard to the public's health, or cause a public nuisance. The National Environmental Policy Act (NEPA) of the U.S. Congress also requires that an environmental assessment be prepared for any proposal which would recieve federal funds. In practice, this means that plans and, if appropriate, an environmental assessment should be submitted to the OEPA. The OEPA engineers and planners would then verify that the proposal is based on sound engineering judgment and that it would not cause significant water pollution or present a threat to the public's health. If federal funds are involved, OEPA would also verify the cost effectiveness of the proposal and consider the overall environmental impact of the proposal.

"It is important for landowners to understand that an approved plan for sludge application does not remove their responsibility for water pollution or health hazards that result from the application of this sludge on their land. Plan approval means that in the judgment of the OEPA, the proposed system should function satisfactorily. However, it is possible that unforeseen problems might arise. In such situations that OEPA would give the landowner a reasonable period of time to rectify the problem. Of course, the landowner should also reserve the option to discontinue sludge application on farmland in the event of such unforeseen problems.

"The local health department would become involved only if a nuisance or health hazard situation were to exist. It is recommended that landowners contact the local health department for guidance and support prior to applying sludge to their land."

ECONOMICS

Equipment Description and Cost

In 1959, a 1953 1-ton Ford truck body was purchased and fitted with a 3.8 cu m (1,000 gal) tank modified with the previously mentioned pipe-baffle plate arrangement. Costs incurred for the original equipment modifications were never recorded. Funds for this work were taken from the general operating budget.

The original spreading equipment was replaced during June, 1975, with a new 1975 Ford 1-ton truck body purchased for approximately $5,000. A tank, purchased in 1971 for $200, was installed. Refitting costs were estimated at $75 for the transfer of the tank to the new truck body.

Records of O&M, labor, and other costs directly related to sludge spreading were never kept separately from other STP expenses. The STP superintendent, was, therefore, asked to estimate expenses for the years of record. These figures are shown in Table 36, but include only fuel and labor. Other costs, such as repair parts for the truck, tires, etc. were not estimated.

Table 37 presents a cost analysis for the sludge spreading operation.

SAMPLING AND ANALYSIS

Sludge

On July 2 and August 25, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the secondary sludge digester.

Soil

On June 2 and 3, 1976, surface and subsurface samples were obtained from both the treated and control plots. As shown in Figures 24 and 25, the treated and control plots were divided into five sections. Approximately 30 random cores from 0 to 18 cm (0 to 7 in) were obtained from each section with a 2.5 cm (1 in) diameter stainless steel split tube sampler. Before each core was taken, the ground was

TABLE 36

WILMINGTON, OHIO - ESTIMATED LABOR AND FUEL COSTS

Calendar Year	Fuel		Labor	Total[1]
	Gas	Oil		
1968	$281	18	$980	$1,779
1969	189	10	650	849
1970	256	20	892	1,168
1971	224	16	680	920
1972	150	16	460	621
1973	221	14	579	814
1974	335	14	681	1,030
1975	319	18	650	987

---

[1] Fuel and labor only

TABLE 37

COST FOR DISPOSAL OF LIQUID SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation[1] 1975 Ford 1-Ton Truck cost: $5,000			$ 848
Stationary Equipment Depreciation			0
Total Annual Capital Cost			$ 848
Annual Operating Cost			
Personnel	Hourly Rate	% Time Worked	
1 Operator	$3.25	10	$ 650
Fringe Benefits (25 percent)			163
Vehicle Maintenance and Operation			337
Total Annual Operating Cost			$1,150
Total Annual Capital and Operating Cost			$1,998
10 Percent Contingency Factor[2]			200
Total Annual Cost			$2,198

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} \quad \frac{\$2{,}198}{\text{90 dry tons}} \quad \frac{\$26.92/\text{dry m ton}}{(\$24.42/\text{dry ton})}$$

---

[1] Vehicle was fully depreciated over 8 years assuming 8 percent interest, equivalent to $169.68 per $1,000 annually.

[2] A 10 percent contingency factor is added to cover such items as administrative overhead.

cleared of miscellaneous non-sludge debris. The sampler was then inserted into the cleared area. Any miscellaneous non-soil debris was discarded from the sampler prior to placing the cores into sampling containers.

Subsurface soil samples were obtained with a 8 cm (3 in) stainless steel bucket auger. At both the treated and control plots, the top 18 cm (7 in) of soil were discarded from the auger. Samples obtained from depths between 18 and 30 cm (7 and 12 in) were labeled A-horizon; B-horizon samples were taken between 30 and 61 cm (12 and 24 in); C-horizon samples were at 61 to 91 cm (24 to 36 in); and D-horizon samples were at 91 to 122 cm (36 to 48 in).

Both surface and subsurface soil samples at the control plot were obtained in exactly the same manner as the treated plot.

Plants

Samples of alfalfa were obtained by shearing the top 20 to 30 cm (8 to 12 in). Approximately 1 kg (2 lbs) of sample representing 20 different cuttings was obtained from each section. Plant samples from the treated and control plots were obtained in an identical manner.

Tables 38 through 44 present the following:

Table	
38	Chemical Characterization of Stabilized Sludges
39	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
40	Total Metal Concentrations in Individual Subsurface Soil Samples
41	Metal Concentrations in Surface Soils and Plants
42	Molybdenum in Composite Plants and Soils
43	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
44	Parasites in Sludges, Soils, and Plants
45	Concentration of Microbes in Sludges, Soils, and Plants

Figures 26 to 35 present particle size analyses of the various soil composites by depth.

TABLE 38

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM WILMINGTON, OHIO

	7/2/76	8/25/76	Average
Volatile Solids (%)	54.07	50.78	52.4
NO_3 - N	26.3	1.15	13.7
NH_4 - N	13906	6836	10146
Organic N	39688	16404	28046
P	51625	19442	35534
K	2738	1481	2110
Na	2875	1115	1995
Ca	43000	19731	31366
Mg	10515	3808	7162
SO_4	181	28.8	105
Cl	3594	1904	2749
Ag	4.06	.77	2.42
As	1.88	.38	1.13
B	51.6	23.3	37.5
Cd	14.8	7.69	11.2
Cr	3216	1256	2236
Co	9.69	4.23	6.96
Cu	525	302	414
Fe	20938	6346	13642
Hg	2.5	1.35	1.93
Mn	316	185	250
Mo	49.4	41.5	45.5
Ni	40	12.7	26.4
Pb	1463	750	1107
Se	5.0	3.46	4.23
Zn	58063	33519	45791
H_2O (%)	96.8	94.8	95.8
pH	7.4	8.1	

All units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 39

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

WILMINGTON , OHIO

PLOT/ DEPTH!	TOTAL METALS (2) CD	CU	NI	ZN	PB	DTPA EXTRACTABLES CD	CU	NI	ZN
	μG/G					μG/G			
TREATED									
SURFACE	0.86	16.0	24.7	190	47.8	0.14	1.86	0.70	27.5
18-30 CM.	0.89	19.0	32.3	62.5	23.5	0.11	0.94	0.85	1.77
30-61 CM.	0.77	22.2	39.0	65.1	22.8	0.09	0.74	0.68	1.08
61-91 CM.	1.00	22.8	44.3	66.0	20.0	0.16	0.66	0.99	0.81
91-122 CM.	1.10	23.0	41.8	67.8	21.4	0.12	0.71	0.98	0.83
CONTROL									
SURFACE	0.87	14.6	24.9	49.5	24.6	0.13	1.38	0.87	1.20
18-20 CM.	0.91	17.6	31.4	57.3	22.1	0.12	0.98	0.47	0.63
30-61 CM.	1.08	21.5	42.3	75.0	22.7	0.11	0.79	0.64	0.60
61-91 CM.	1.08	23.4	46.2	74.2	21.9	0.08	0.69	0.38	0.57
91-122 CM.	1.06	24.8	44.5	71.3	20.1	0.09	0.79	0.38	0.62

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 40

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES(1)

WILMINGTON , OHIO

SECTION/ DEPTH	TREATED				CONTROL			
	CD	CU	NI	ZN	CD	CU	NI	ZN
	μG/G				μG/G			
SECTION 1								
18-30 CM.	0.63	15.5	27.9	53.7	0.86	16.3	28.1	53.3
30-61 CM.	0.65	22.7	35.6	69.6	0.96	23.3	28.9	73.9
61-91 CM.	0.90	22.0	39.7	66.4	1.07	23.2	42.4	67.0
91-122 CM.	1.32	22.4	38.3	63.4	1.16	24.1	45.6	70.0
SECTION 2								
18-30 CM.	0.75	17.8	36.0	60.9	0.92	17.8	30.9	59.0
30-61 CM.	0.80	21.3	35.6	63.6	1.00	20.9	41.8	72.4
61-91 CM.	0.76	23.3	40.6	64.8	1.12	24.0	45.3	72.7
91-122 CM.	1.05	24.8	41.7	69.0	1.07	24.9	44.0	73.1
SECTION 3								
18-30 CM.	0.73	19.4	38.9	61.2	0.98	16.4	33.1	60.7
30-61 CM.	0.92	23.2	39.9	70.5	1.19	20.9	43.2	76.0
61-91 CM.	0.96	24.3	44.5	62.5	1.37	21.6	45.8	75.8
91-122 CM.	0.82	23.4	39.3	61.1	1.01	24.1	42.1	71.1
SECTION 4								
18-30 CM.	0.79	18.1	34.4	58.4	0.99	17.7	32.9	62.9
30-61 CM.	0.75	20.0	36.4	61.9	1.06	23.8	42.0	50.6
61-91 CM.	1.05	24.4	44.6	69.1	1.24	23.5	45.8	74.4
91-122 CM.	0.94	21.5	39.9	61.4	1.12	23.9	44.9	71.1
SECTION 5								
18-30 CM.	1.00	22.7	37.6	71.0	0.83	19.3	31.8	58.4
30-61 CM.	1.02	21.7	40.6	68.2	1.00	23.4	42.5	92.0
61-91 CM.	1.02	23.2	41.6	64.9	0.97	23.9	47.9	72.6
91-122 CM.	1.18	23.0	39.1	67.5	1.08	26.1	46.4	71.8

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 41

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS (1)

WILMINGTON , OHIO

SAMPLE	SURFACE SOIL					PLANT					
	CD	CU	NI	ZN	PB (2)	CD	CU	NI	ZN	PB (2)	ORG-N (2)
	µG/G					µG/G					
TREATED											
COMPOSITE	0.86	16.00	24.70	190.00	47.80	0.90	8.91	6.43	37.80	6.30	3.67
SECTION 1	0.79	14.30	21.10	100.00		1.02	9.10	7.62	43.30		
SECTION 2	1.27	15.00	23.70	104.00		0.83	8.51	7.24	42.40		
SECTION 3	0.87	16.60	25.30	169.00		0.84	7.62	5.90	37.60		
SECTION 4	0.86	16.70	26.10	137.00		0.93	8.41	8.35	38.10		
SECTION 5	0.96	16.70	25.10	184.00		0.79	7.77	7.76	41.30		
MEAN	0.95	15.7	24.3	139		0.88	8.26	7.37	40.5		
STD. DEV.	0.19	1.13	1.97	37.7		0.09	0.60	0.92	2.56		
CONTROL											
COMPOSITE	0.87	14.60	24.90	49.50	24.60	1.00	9.40	7.18	37.00	7.79	3.43
SECTION 1	0.83	12.70	22.60	47.00		0.75	9.90	7.73	33.50		
SECTION 2	0.85	12.90	23.50	46.00		1.10	9.95	7.87	34.10		
SECTION 3	0.85	15.50	25.30	51.00		0.56	9.70	9.04	34.30		
SECTION 4	0.93	14.70	28.30	52.00		0.84	8.11	7.96	27.30		
SECTION 5	0.87	15.50	25.90	50.00		1.01	8.46	8.75	32.80		
MEAN	0.87	14.3	25.1	49.2		0.65	9.22	8.27	32.40		
STD. DEV.	0.04	1.37	2.22	2.59		0.21	0.87	0.59	2.91		

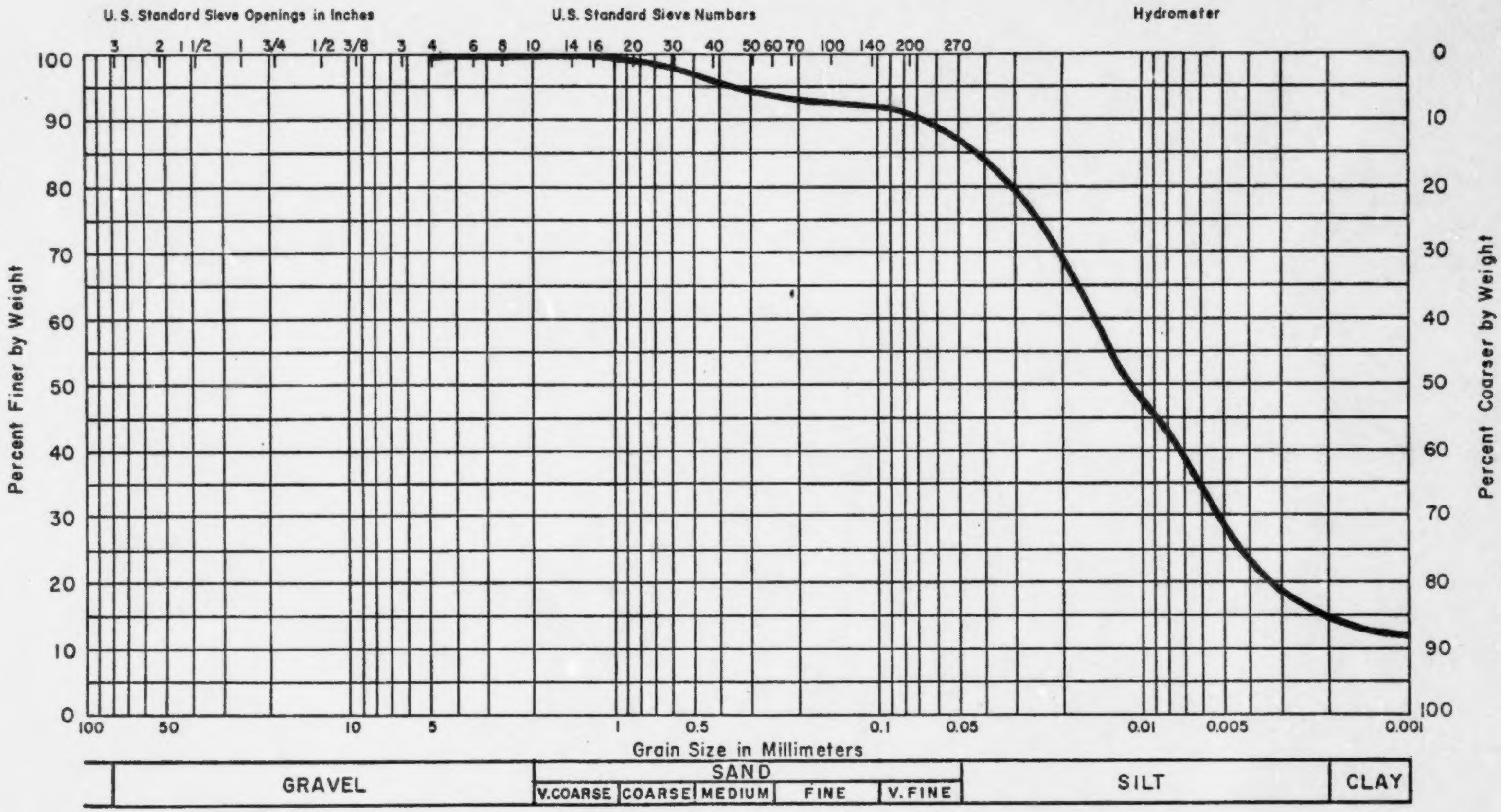
(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.

TABLE 42

MOLYBDENUM IN COMPOSITE PLANTS AND SOILS

Wilmington, Ohio

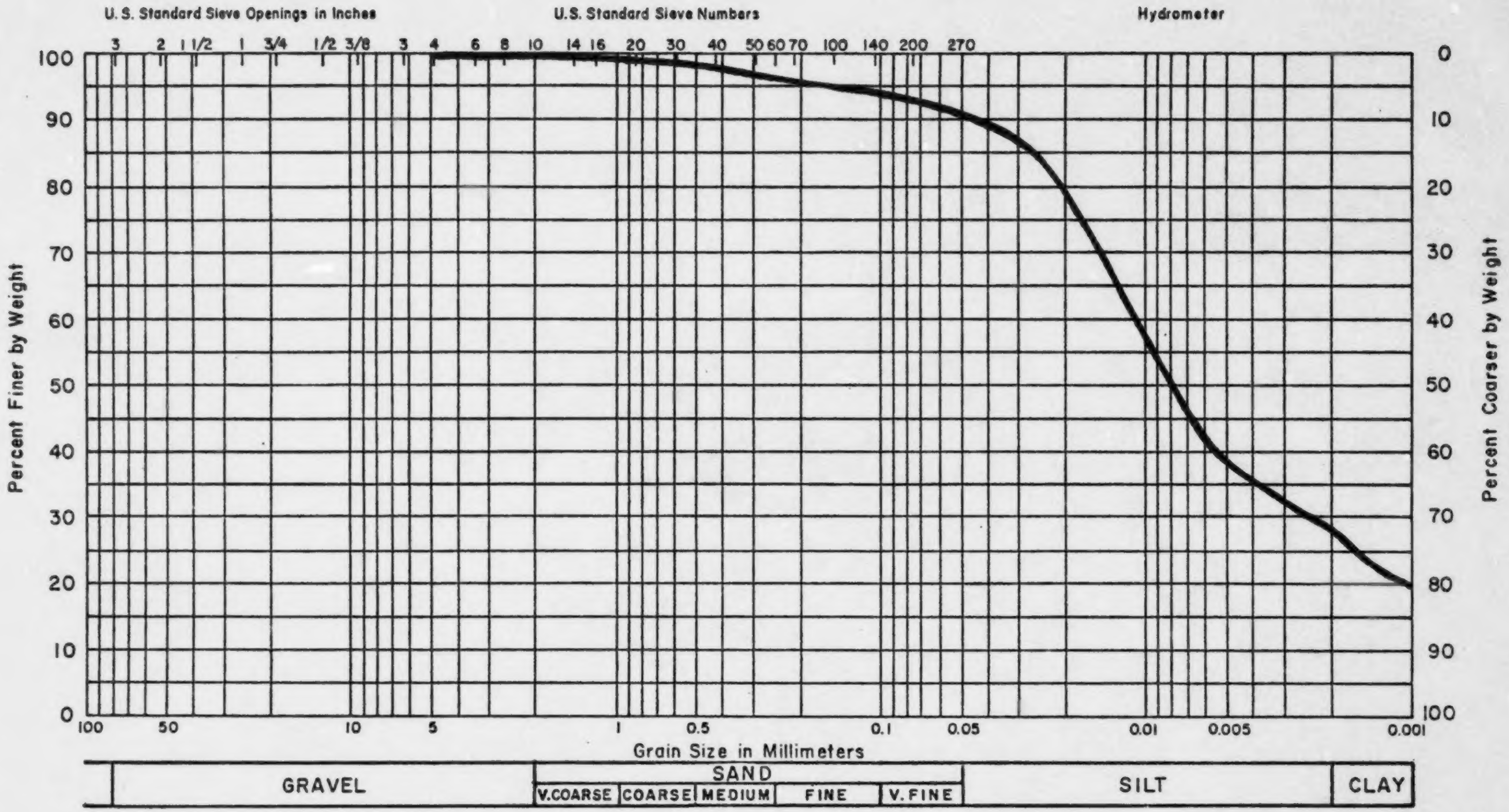
	Treated Plot	Control Plot
	µg/g	
Plant (alfalfa)		
Soil (depth in cm)		
0-18	2.00	1.97
18-30	2.63	2.60
30-61	2.98	1.80
61-91	2.53	1.80
91-122	3.25	3.10



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1052	Wilmington	13	73	14	Silt Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

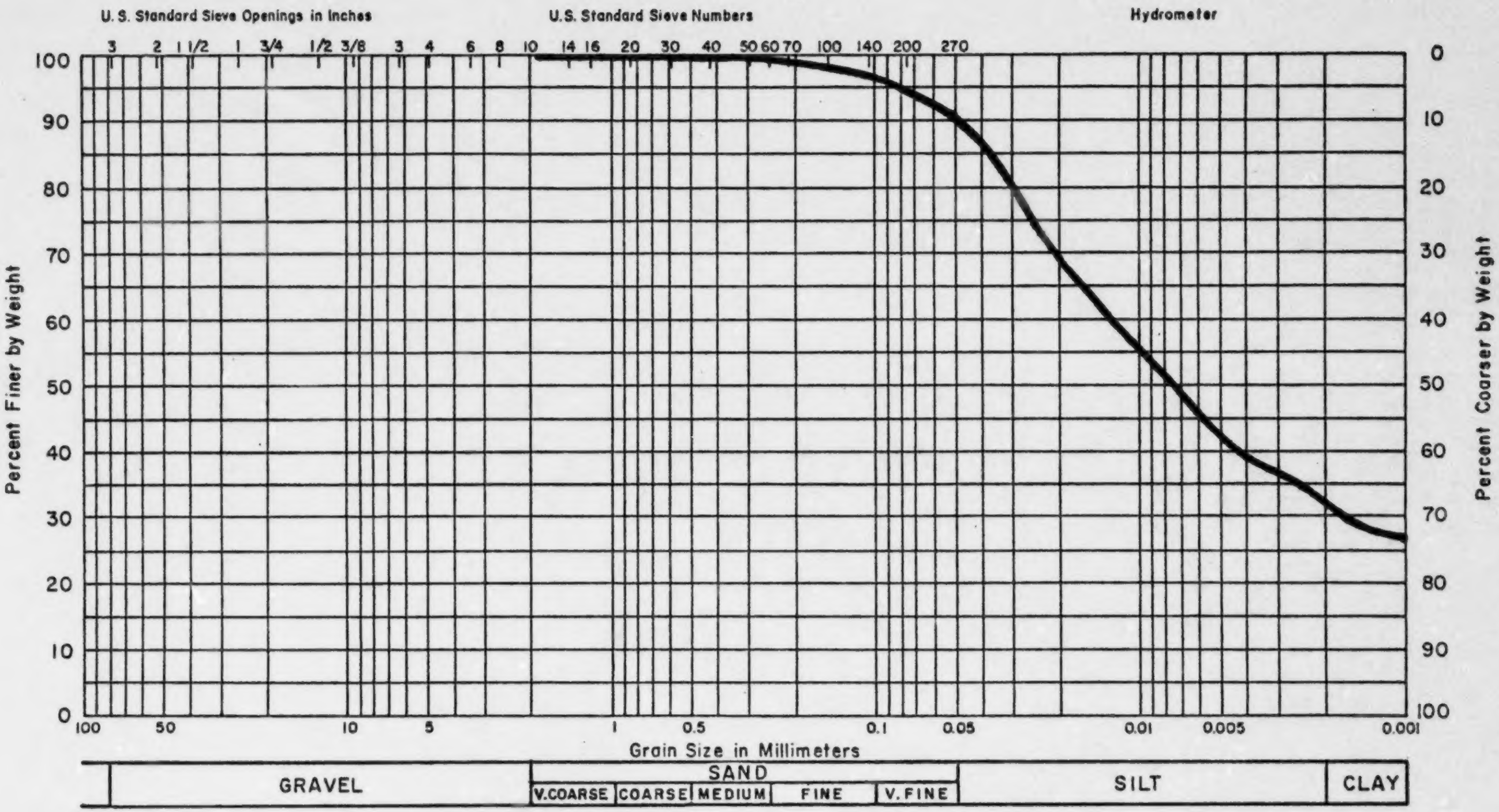
Figure 26 Wilmington, Ohio Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1058	Wilmington	9	64	27	Silty Clay Loam/Silt Loam
	Treated				
	18-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

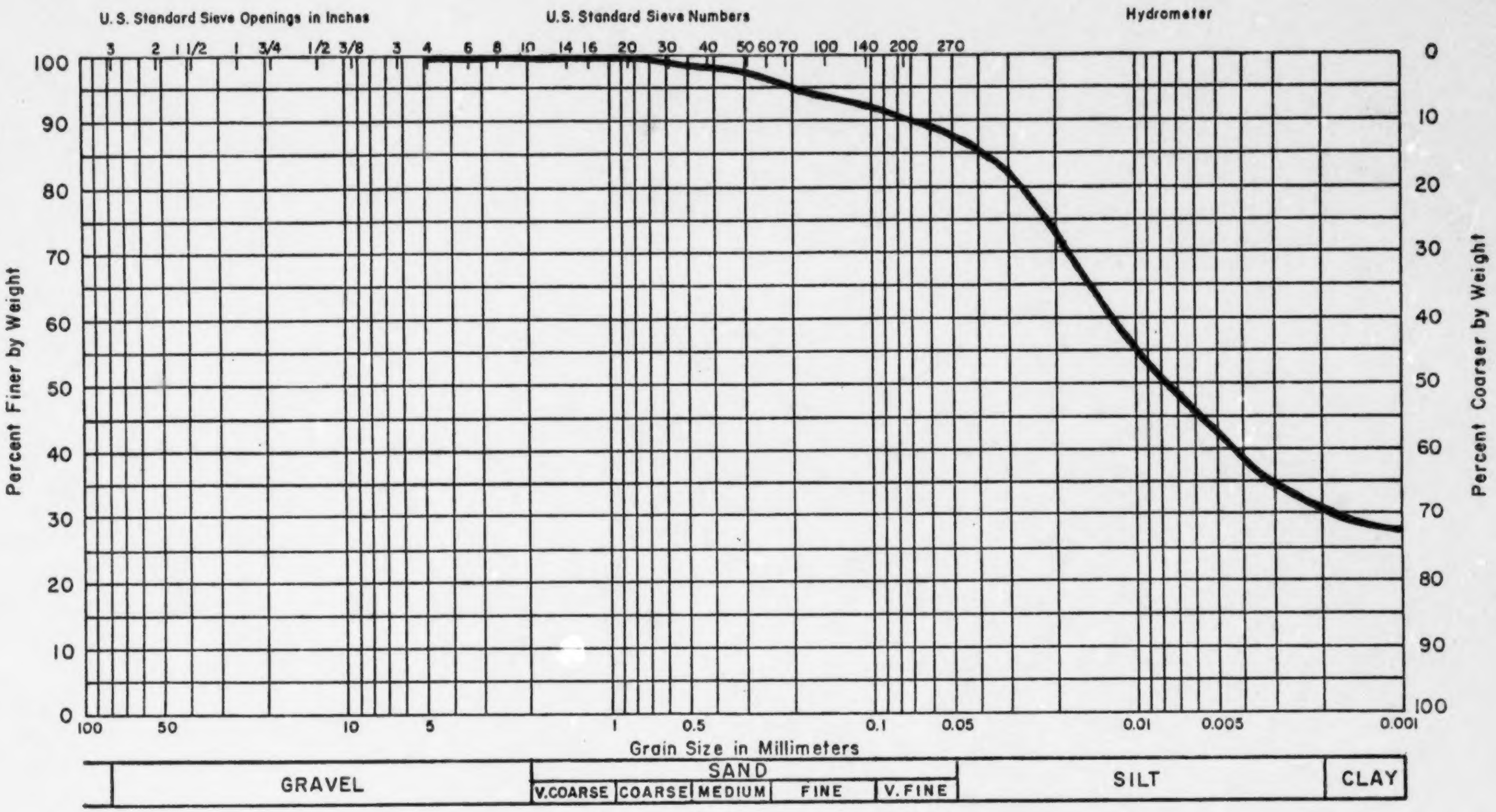
Figure 27 Wilmington, Ohio Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1064	Wilmington	9	59	32	Silty Clay Loam
	Treated				
	30-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

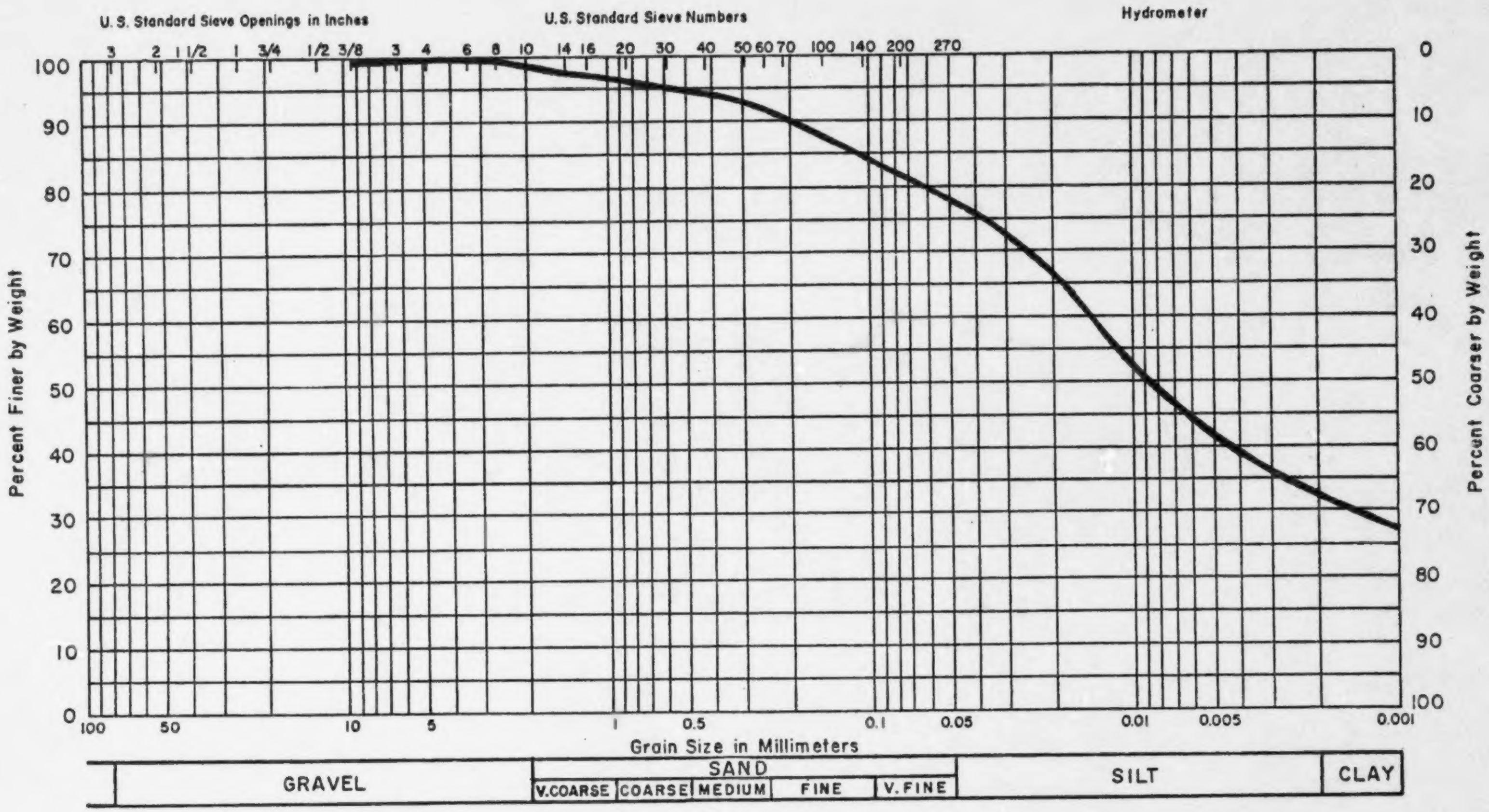
Figure 28 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1070	Wilmington	12	58	30	Silty Clay Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

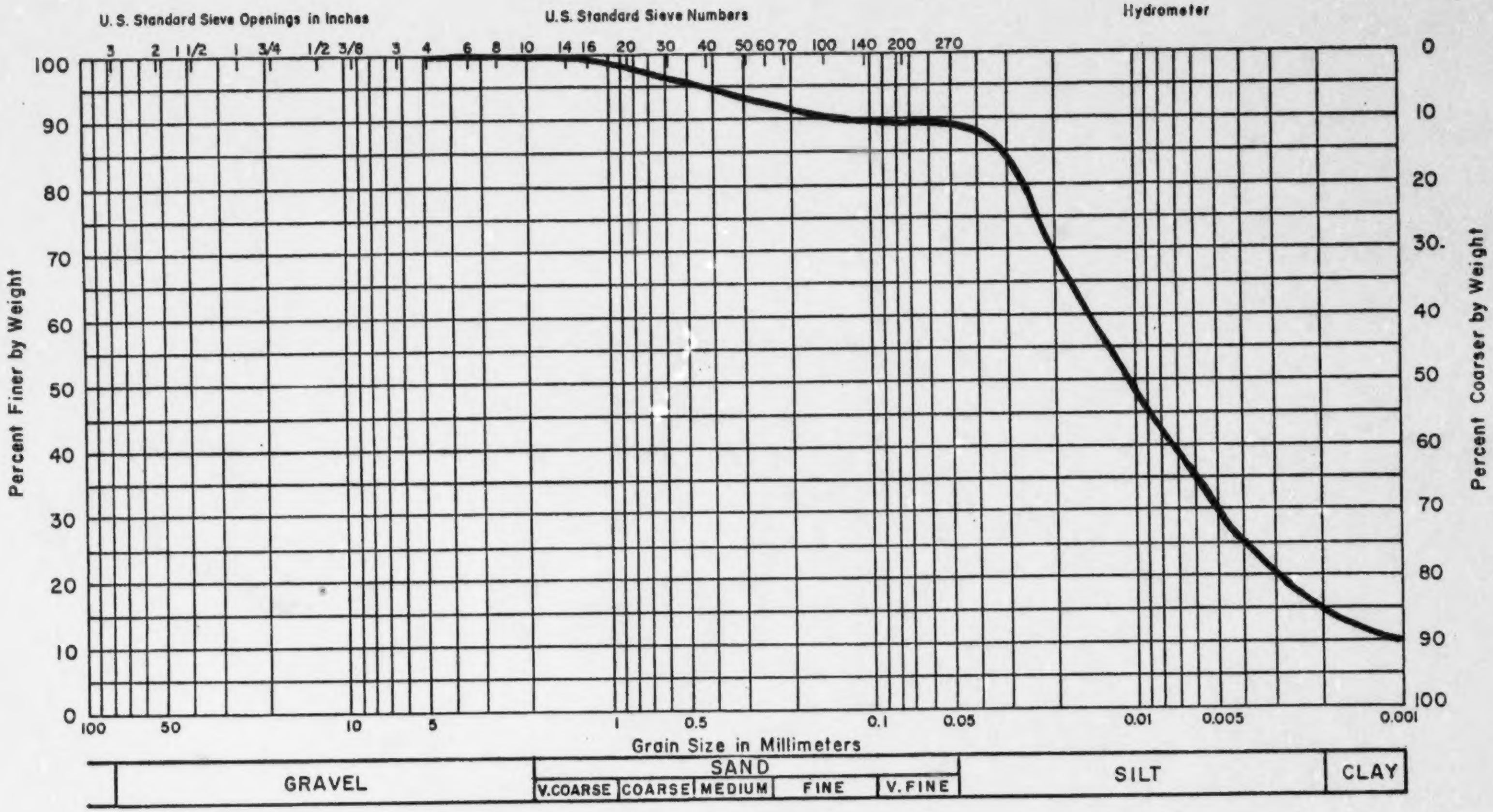
Figure 29 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1076	Wilmington	21	47	32	Clay Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

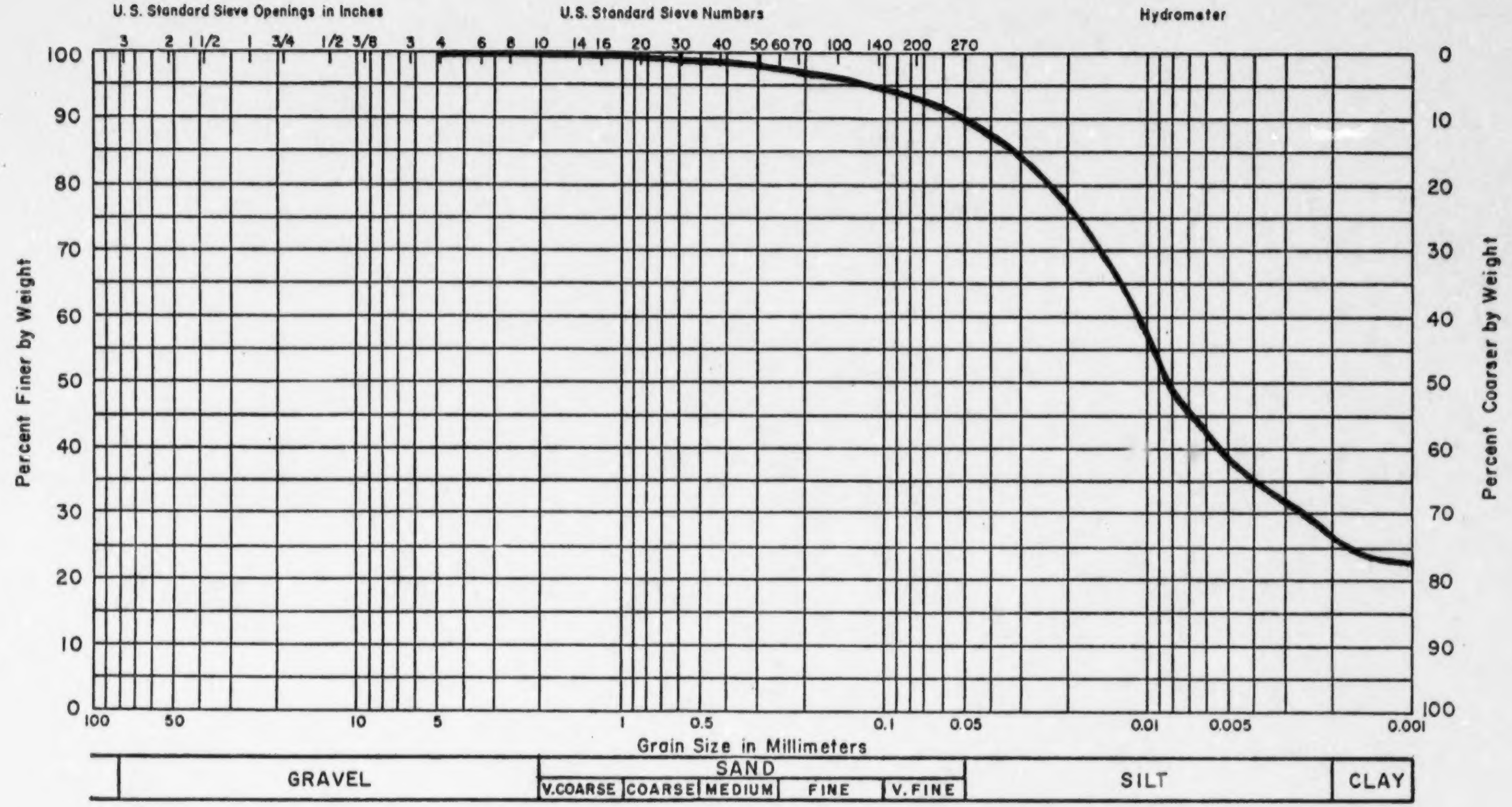
Figure 30 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1022	Wilmington	10	76	14	Silt Loam
	Control				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

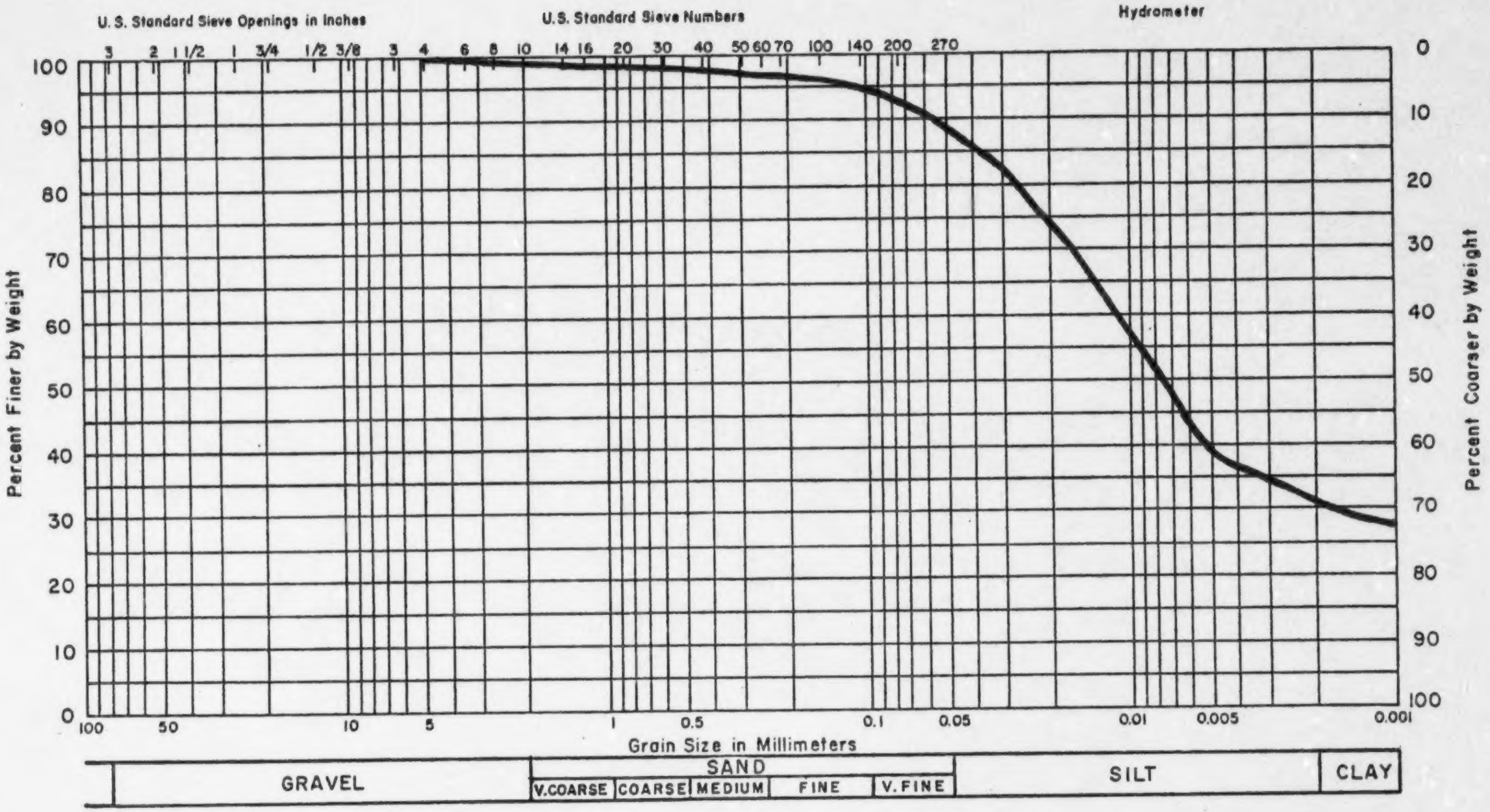
Figure 31 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1028	Wilmington	13	62	25	Silt Loam
	Control				
	18-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

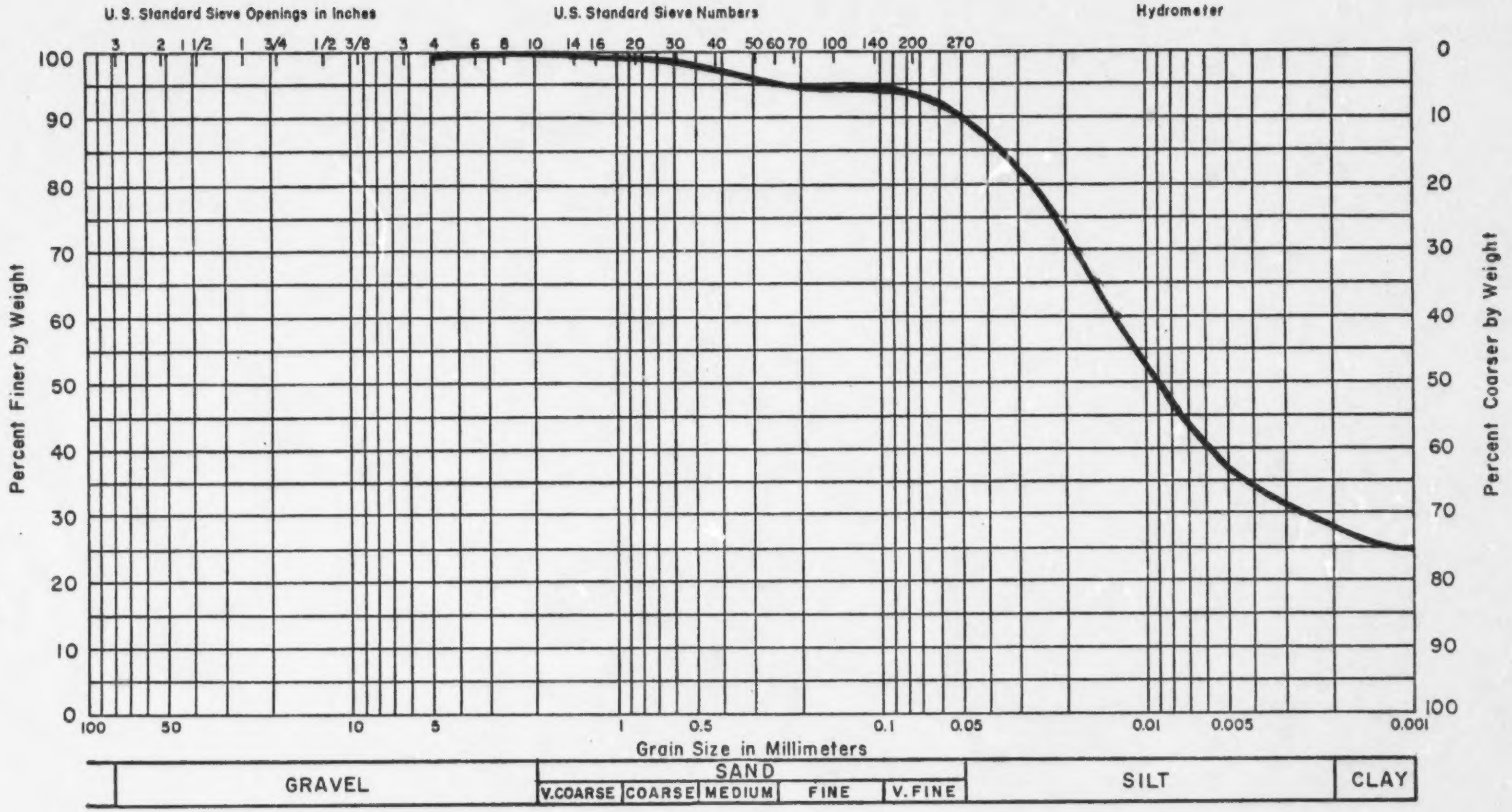
Figure 32 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1034	Wilmington	9	61	30	Silty Clay Loam
	Control				
	30-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

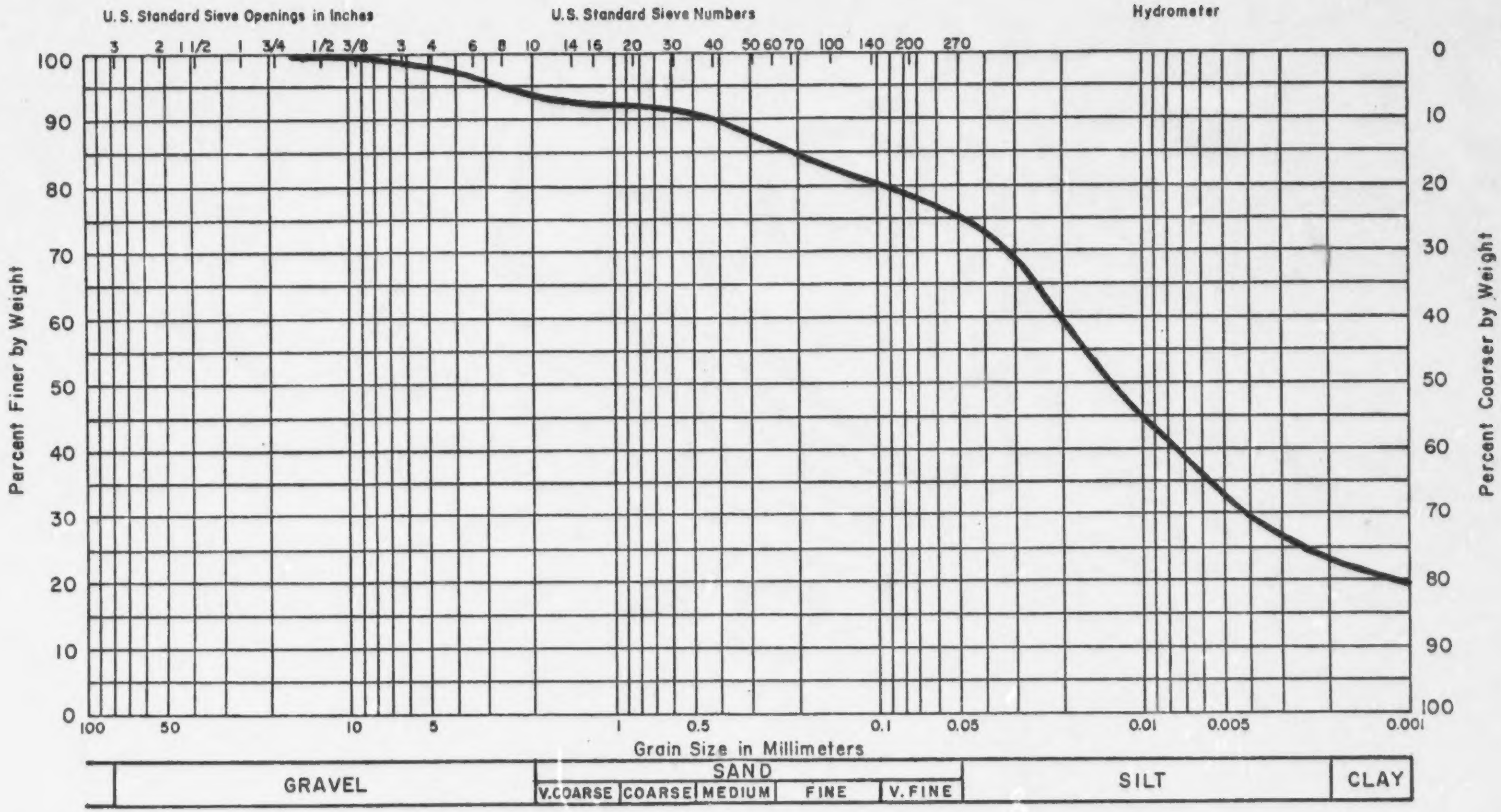
Figure 33 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1040	Wilmington	10	63	27	Silty Clay Loam/Silt Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 34 Wilmington, Ohio, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1046	Wilmington	20	55	25	Silt Loam
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 35 Wilmington, Ohio, Particle Size Analysis

TABLE 43

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

WILMINGTON, OHIO

	Treated Plot	Control Plot	
	. . . . µg/kg	. . . .	Chlorinated Hydrocarbon
Soil			
Surface Composites	<0.01[1]	<0.01	DDT
	0.84	0.01	DIELDRIN
	<0.5	<0.5	PCB 1221
	99	<0.4	PCB 1248
Plant			
Composites	<0.02	<0.02	DDT
	<0.04	<0.04	DIELDRIN
	<1	<1	PCB 1221
	<1	<0.11	PCB 1248
	7/2/76	8/25/76	
Stabilized Sludge	<0.31	0.19	DDT
	<0.63	1.35	DIELDRIN
	<.1	<.1	PCB 1221
	1566	4731	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 44

PARASITES IN SLUDGES, SOILS, AND PLANTS

WILMINGTON, OHIO

Sample Description	Results
Sludge	
Raw (7/2/76)	Negative
Raw (8/25/76)	Negative
Stabilized (7/2/76)	Negative
Stabilized (8/25/76)	Negative
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
18-30 cm	Negative
30-61 cm	Negative
61-91 cm	Negative
91-111 cm	Negative
Soils - Control Composites	
Surface	Negative
18-30 cm	Netative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 45

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
WILMINGTON, OHIO

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 7/2	1.29×10^{7}	ND	+	+	-	ND	+	+	-	1.6×10^{4}	+	+	+	1.6×10^{6}	+	+	+
Raw 8/25	1.33×10^{10}	ND	+	-	-	ND	+	-	-	560	+	+	+	3.5×10^{8}	+	+	+
Stab 7/2	1.0×10^{8}	ND	+	+	-	ND	+	+	-	22.0×10^{4}	+	+	+	1.4×10^{6}	+	+	+
Stab 8/25	1.17×10^{10}	ND	+	-	-	ND	+	-	-	2.4×10^{6}	+	+	+	2.4×10^{7}	+	+	+
Plants																	
Treated	1.28×10^{10}	ND	+	+	-	ND	+	+	-	11.0×10^{3}	+	+	+	2.0×10^{4}	+	+	+
Control	3.57×10^{10}	ND	+	+	-	ND	+	+	-	73	+	+	+	1.2×10^{4}	+	+	+

[1] All results expressed on a dry weight basis.

*Values expressed as a power of 10 (i.e., 10^{4}).

**Observations reported as + or -.

ND = none detected.

III-14

TABLE 45 (Continued)

Sample Description	Total Aerobic Bact per g Sludge (10^7)	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites																	
Surface	1.82	ND	+	-	-	ND	+	-	-	ND	+	-	-	1,400	+	+	+
18-30 cm	2.70	ND	+	-	-	ND	+	-	-	11	+	+	+	2,900	+	+	+
30-61 cm	0.46	ND	+	+	-	ND	+	+	-	27	+	+	+	180	+	+	+
61-91 cm	0.79	ND	+	+	-	ND	+	+	-	ND	+	-	-	1,600	+	+	+
91-122 cm	0.70	ND	+	-	-	ND	+	-	-	ND	+	-	-	1,300	+	+	+
Soils - Control Composites																	
Surface	1.66	ND	+	-	-	ND	+	-	-	ND	+	+	-	3,000	+	+	+
18-30 cm	1.07	ND	+	-	-	ND	+	-	-	11	+	+	+	2,800	+	+	+
30-61 cm	11.3	ND	+	-	-	ND	+	-	-	ND	+	-	-	2,800	+	+	+
61-91 cm	0.67	ND	+	-	-	ND	+	-	-	4.7	+	+	+	33	+	+	+
91-122 cm	1.71	ND	+	-	-	ND	+	-	-	ND	+	-	-	2,900	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER IV

SPRINGFIELD, MISSOURI

SITE DESCRIPTION

Location

This study site is located southwest of Springfield, Missouri, approximately 10 km (6 mi) from the downtown area. The treated field is located to the west and immediately adjacent to the Southwest Wastewater Treatment Plant (STP). The control field is located approximately 2.5 km (1.5 mi) west of the Springfield city limits and 6 km (4 mi) northwest of the STP.

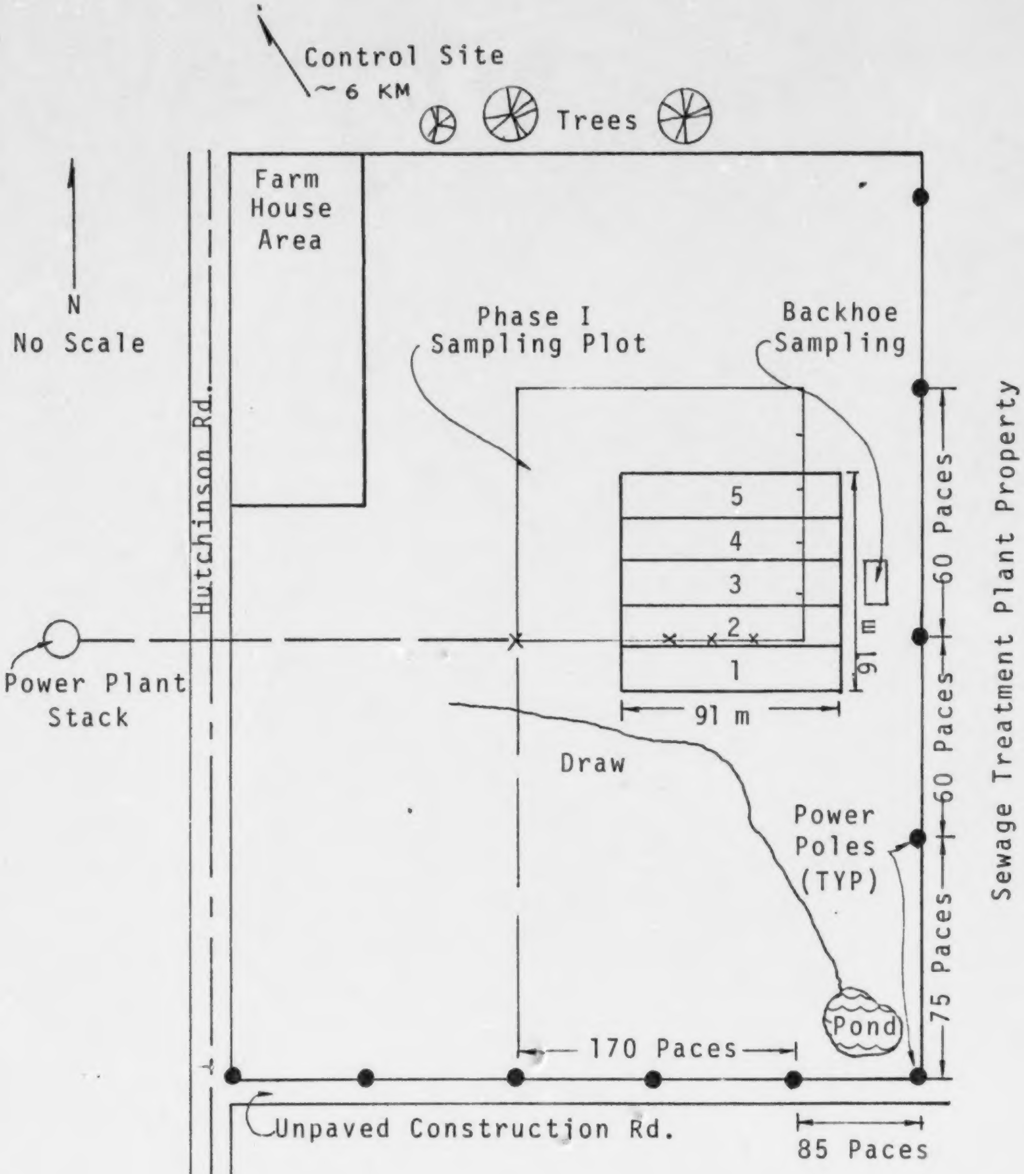
Physical Conditions

The treated 12.6 ha (31 acres) is gently sloping (about 2 percent and decreases in elevation from west to east. As shown in Figure 36, a draw runs through the pasture which carries runoff to a small 15 m (50 ft) diameter pond in the corner of the property

The location of the control plot is shown in Figure 37 The southern end of the control plot is located in the middle of an 8.1 ha (20 acre) field. The topography of the plot is approximately the same as that of the treated plot.

At the time of sampling, May 17, 1976, the treated field was in tall fescue (Festuca elatior arundinacea). The control field vegetation was a mixture of tall fescue and clover.

The water table lies an estimated 41 m (135 ft) below the surface.



Control Site
~6 KM
Trees
N
No Scale
Farm House Area
Hutchinson Rd.
Phase I Sampling Plot
Backhoe Sampling
5
4
3
2
1
91 m
91 m
Power Plant Stack
Draw
Power Poles (TYP)
Pond
60 Paces
60 Paces
75 Paces
Sewage Treatment Plant Property
170 Paces
Unpaved Construction Rd.
85 Paces

Figure 36 Treated Plot

155

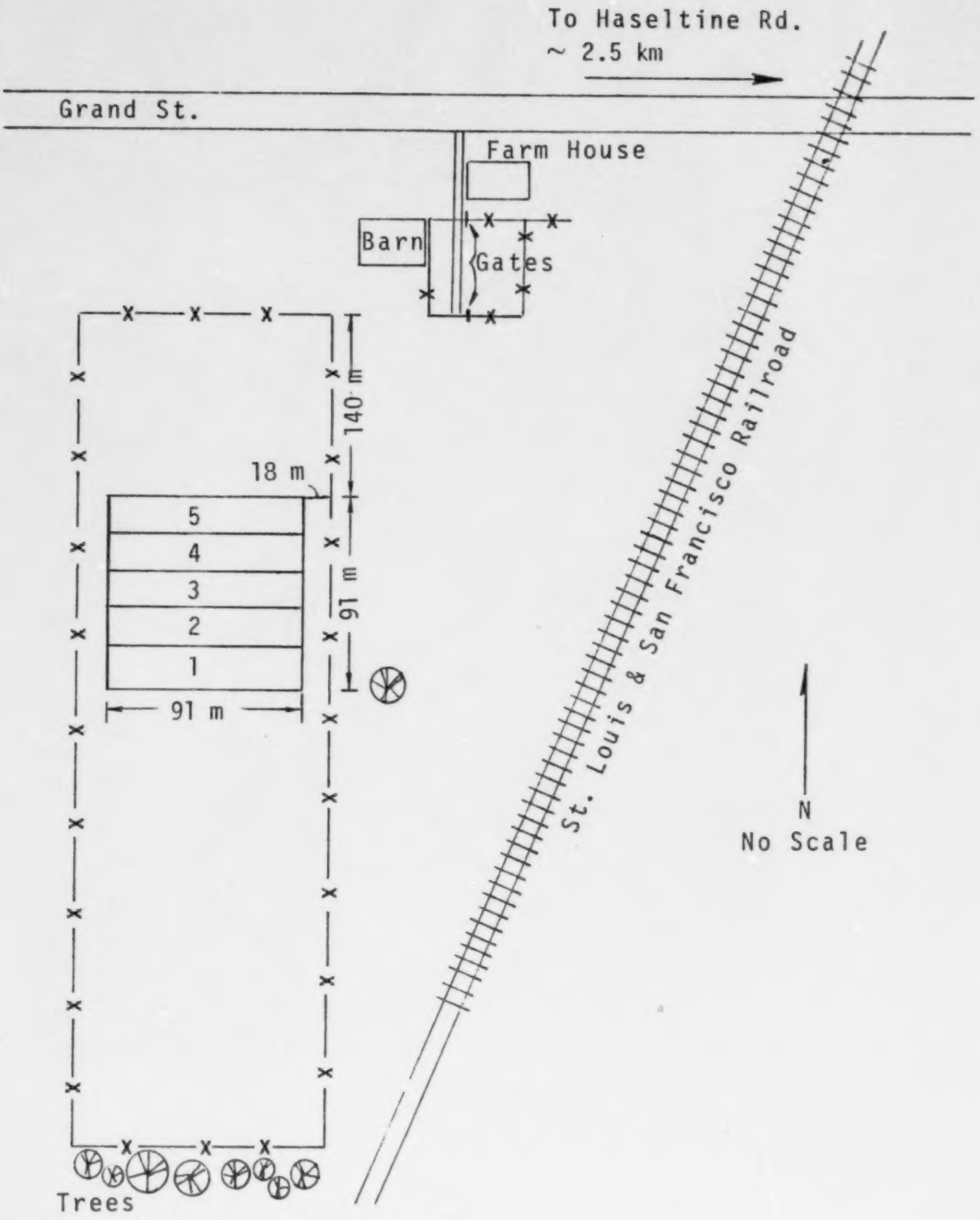

To Haseltine Rd.
~ 2.5 km
Grand St.
Farm House
Barn
Gates
140 m
18 m
5
4
3
2
1
91 m
91 m
St. Louis & San Francisco Railroad
N
No Scale
Trees

Figure 37 Control Plot

157

Farming Practices

Since sludge was first applied to the treated field in about 1961, a variety of grasses and crops have been grown. Various certified seed crops including barley, wheat, and milo (grain sorghum) were grown from 1960 to 1964; and from 1964 to 1970, the field was in orchard grass. In 1970 the field was plowed and corn planted. The following year soybeans were planted, but the crop was lost due to wet weather.

In 1972 a mixture of wheat and tall fescue was grown. From late 1973 through early 1976, the field was in fescue and used exclusively for grazing cattle. Later in 1976, however, the fescue was used as a seed crop which was harvested in June. The field will be pastured again in the fall of 1976 following an application of sludge and normal regrowth.

STP personnel have maintained sludge distribution records since 1963. Assuming an average 3 percent sludge solids (STP data), the annual application rate over the last 12 years has been 15.8 dry m tons/ha (7.0 dry tons/acre). Table 46 presents the average annual application rates.

Historically, the control field has been in permanent pasture. In 1971 it was seeded with a mixture of rye and tall fescue. The rye was allowed to grow to a height of approximately 1.5 m (5 ft) and then cut and baled. In March, 1975, clover was sown.

At the time of sampling in mid-May, 1976, the field was a mixture of clover and fescue. During late May and early June,

TABLE 46

SPRINGFIELD, MISSOURI - APPLICATION RATES

Year	Dry Metric tons/ha[1]
1963	21.6
1965	14.4
1966	8.2
1967	18.4
1968	11.8
1969	21.6
1970	13.2
1971	20.8
1972	20.2
1973	16.9
1974	12.9
1975	9.0
Total	189.0
Average	15.8

---

[1] Based on 3 percent sludge solids (STP data).

1976, the clover took over and grew to a height of approximately 61 cm (24 in). In mid-June approximately 1270 bales of clover were harvested.

In early 1975 a phosphorus-potash fertilizer was applied to the field. Information on the exact type of fertilizer and the application rate was not available. The height of the fescue at the time of sampling was approximately 25 to 26 cm (10 to 14 in).

CLIMATE

This tableland area is practically at the top of the crest of the Missouri-Ozark mountain plateau. The average elevation of the city proper is slightly over 396 m (1300 ft) above mean sea level.

Normal precipitation is well distributed, the three winter months normally being the driest. The distribution is considered to be excellent from an agricultural standpoint, and the climate permits green pasturing the year round. Since 1935 the annual precipitation has exceeded 127 cm (50 in) only on three occasions and dropped below 51 cm (20 in) only six times. The average annual precipitation is 100.8 cm (39.7 in) based on records from the period 1941 to 1970. Snow normally falls in small amounts during all winter months from November through March.

The average growing season is 199 days, from April 9 to October 25. The mean average temperature is 13.4°C (56.1°F), with a mean daily maximum of 19.5°C (67.2°F) and daily minimum of 7.2°C (45.0°F). Additional meterological data are presented in Table 47.

SOIL DESCRIPTION

Regional Area

The soil from the treated and control plots and most of the surrounding land is mapped as Britwater silt loam. This soil is typically found on gently sloping (2 to 5 percent) ridge tops of upland divides and stream terraces. Parcels of Britwater silt loam often include 5 to 10 percent Goss soil, 5 to 15 percent Viraton soil, and 5 to 10 percent Unnamed and Ponder silt loams. The Goss soil is normally found on side slopes at low elevations and the Viraton soil on smooth broad ridge tops. The Unnamed and Ponder silt loams are on valley foot slopes. The total of all these inclusions rarely exceeds 30 percent.

The soil of the Britwater series is typically deep, well-drained, and moderately permeable, having loamy surface and subsoil layers. It was formed in limestone residuum or thin, old silty alluvium, or loess over limestone residuum under deciduous forests.

A representative profile of Britwater silt loam (2 to 5 percent slope) is characterized by the Government Conservation Service as follows:

- 15.2 to 22.9 cm (0 to 9 in) - dark brown silt loam; moderate, very fine, and fine, granular structure; very friable; few chert; few iron and manganese concretions; medium acidity.

TABLE 47

SPRINGFIELD, MISSOURI

Meteorological Data For The Current Year

Station SPRINGFIELD, MISSOURI * Standard time used: CENTRAL Latitude: 37° 14' N Longitude 93° 23' W Elevation (ground): 1268 feet Year: 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity, pct.			
	Averages			Extremes						Water equivalent			Snow, Ice pellets			Hour 00	Hour 06	Hour 12	Hour 18
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	(Local time)			
JAN	47.4	25.4	36.4	67	29	7	20	878	0	3.95	2.23	30-31	0.4	0.4	19	72	74	57	64
FEB	43.6	25.0	34.3	63	21	3	9	851	0	3.93	2.01	22	13.0	11.9	23	75	80	63	70
MAR	50.4	30.4	40.4	80	21	15	14	757	1	6.32	1.78	11	11.5	9.1	9-10	71	74	57	57
APR	67.1	42.0	54.6	83	27	19	3	334	27	3.45	1.59	24	T	T	3	71	78	52	49
MAY	78.6	54.3	66.5	88	22	37	1	55	110	1.96	0.71	29	0.0	0.0		83	87	57	60
JUN	86.1	62.8	74.5	91	20	46	1	3	291	11.31	4.83	9-10	0.0	0.0		86	89	60	62
JUL	90.5	64.4	77.5	98	6	49	13	0	394	1.85	0.75	28	0.0	0.0		86	89	49	56
AUG	88.2	64.8	76.5	96	12	54	9	0	364	2.57	1.23	29-30	0.0	0.0		87	95	56	57
SEP	74.6	51.9	63.3	95	3	34	26	152	109	11.36	4.63	10	0.0	0.0		90	95	62	68
OCT	71.1	45.8	58.5	89	11	31	19	245	52	1.05	0.51	24	0.0	0.0		79	85	53	59
NOV	58.7	36.5	47.6	79	8	7	27	515	1	4.24	1.89	29	6.9	6.7	25-26	76	81	59	67
DEC	47.8	29.3	38.6	69	14	6	18	815	0	1.95	0.74	5	3.4	1.8	25	78	80	66	74
YEAR	67.0	44.4	55.7	98	JUL 6	3	FEB 9	4605	1349	53.94	4.83	JUN 9-10	35.2	11.9	FEB 23	80	84	58	62

Month	Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F				Elev. 1270 feet m.s.l.
	Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy					Maximum (b) 90° and above	Maximum 32° and below	Minimum 32° and below	Minimum 0° and below	
JAN	22	3.1	11.8	34	NW	25	62	5.6	10	11	10	10	0	2	0	0	2	22	0	971.6
FEB	32	0.9	11.7	27	N	23	48	7.5	5	5	18	11	1	2	2	0	4	22	0	970.9
MAR	21	1.3	12.7	40	SE	26	54	6.5	8	9	14	12	2	5	3	0	3	21	0	969.2
APR	17	5.3	11.0	37	SW	29	72	5.3	10	10	10	12	0	8	2	0	0	5	0	970.2
MAY	17	3.7	8.1	45	S	20	78	5.3	10	10	11	6	0	6	1	0	0	0	0	968.2
JUN	18	5.2	8.2	32	E	9	75	5.2	10	11	9	12	0	16	1	13	0	0	0	969.9
JUL	18	1.6	6.4	40	NE	28	80	4.5	14	13	4	6	0	8	0	19	0	0	0	971.2
AUG	17	4.5	7.7	25	NE	30	71	4.6	14	7	10	10	0	9	2	11	0	0	0	972.2
SEP	13	1.2	7.1	28	N	18	66	5.2	13	3	14	9	0	7	1	4	0	0	0	973.9
OCT	16	4.0	8.7	25	S	23	77	3.2	18	7	6	4	0	3	1	0	0	2	0	973.6
NOV	18	5.5	11.3	33	SE	29	51	5.4	10	9	11	12	1	2	2	0	2	12	0	972.2
DEC	18	1.8	9.3	27	S	14	42	6.7	8	5	18	11	2	1	6	0	2	21	0	973.9
YEAR	18	2.9	9.5	45	S	MAY 20	66	5.4	130	100	135	115	6	69	21	47	13	105	0	971.4

TABLE-47 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches											Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days											Average station pressure mb.
	Normal			Extremes						Water equivalent							Snow, Ice pellets				Hour 00	Hour 06	Hour 12	Hour 18			Fastest mile					Sunrise to sunset							Temperatures °F				Elev. 1270 feet m.s.l.
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year	(Local time)				Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Max. (b) 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	
(a)				16		16					30		30		30		30		30		15	15	15	15	30	14	30	30		30	30	30	30	30	30	30	30	30	15	15	15	15	3
J	43.2	22.6	32.9	75	1965	-10	1963	995	0	1.67	6.77	1950	0.08	1961	3.91	1950	10.4	1956	5.1	1973	73	77	60	64	12.2	SSE	55	SW	1959	50	6.5	8	7	16	8	1	1	4	0	7	26	2	972.7
F	47.5	26.5	37.0	81	1972	-10	1971	784	0	2.22	5.34	1955	0.35	1947	3.73	1966	15.1	1960	11.9	1975	73	78	58	61	12.6	SSE	59	S	1953	54	6.3	8	6	14	9	1	1	3	0	3	22	*	971.9
M	55.1	32.8	44.0	87	1974	5	1967	660	9	2.99	9.01	1973	0.50	1956	4.09	1974	23.9	1970	15.7	1970	71	78	55	55	13.6	SSE	65	SW	1960	56	6.5	7	8	16	10	1	4	2	0	1	14	0	967.8
A	68.0	45.0	56.5	93	1963	19	1975	275	20	4.27	7.40	1965	0.86	1955	3.85	1970	7.1	1971	6.9	1971	71	78	55	54	13.0	SSE	65	SW	1965	61	6.2	8	8	14	11	*	6	1	*	0	4	0	969.0
M	76.1	54.0	65.1	93	1972	30	1970	94	98	4.93	10.54	1957	1.54	1969	2.86	1961	0.0		0.0		80	84	57	59	11.1	SSE	66	W	1946	64	6.0	8	10	13	11	0	9	1	*	0	*	0	967.6
J	84.2	62.9	73.6	100	1963	42	1966	10	268	4.72	11.31	1975	0.58	1952	4.83	1975	0.0		0.0		83	85	59	61	10.3	SSE	57	N	1959	68	5.6	9	10	11	10	0	10	1	6	0	0	0	969.4
J	89.0	66.5	77.8	102	1974	44	1972	0	401	3.62	18.75	1958	0.33	1953	6.85	1958	0.0		0.0		83	86	56	57	8.9	SSE	56	NW	1955	72	5.2	11	11	9	9	0	8	1	16	0	0	0	971.4
A	88.9	65.2	77.1	102	1964	44	1967	6	381	2.94	6.95	1952	0.50	1955	3.07	1950	0.0		0.0		82	87	53	56	9.0	SSE	59	W	1954	73	4.9	12	10	9	9	0	8	1	14	0	0	0	972.1
S	81.2	57.3	69.3	100	1960	33	1967	35	164	4.11	11.36	1975	0.20	1952	4.74	1962	0.0		0.0		85	89	61	67	9.8	SSE	54	S	1959	69	4.9	12	8	10	9	0	6	2	3	0	0	0	972.9
O	71.1	46.8	59.0	92	1963	23	1969	227	41	3.44	8.70	1967	0.43	1963	5.48	1949	0.6	1951	0.6	1951	79	83	54	63	10.6	SSE	49	S	1951	66	4.7	14	7	10	7	0	3	2	*	0	3	0	974.3
N	56.4	34.5	45.5	79	1975	6	1970	585	0	2.34	8.14	1946	0.35	1955	4.49	1973	19.5	1951	12.5	1951	77	81	59	68	11.8	SSE	59	SE	1961	55	5.7	11	6	13	8	*	2	2	0	*	13	0	972.1
D	45.7	26.3	36.0	74	1966	-8	1966	899	0	2.45	6.24	1971	0.13	1950	2.62	1968	13.9	1969	7.5	1966	77	80	64	70	12.0	SSE	60	SE	1971	48	6.4	8	7	16	9	1	1	3	0	5	23	1	971.9
YR	67.2	45.0	56.1	102	JUL 1974	-10	FEB 1971	4570	1382	39.70	18.75	JUL 1958	0.08	JAN 1961	6.85	JUL 1958	23.9	MAR 1970	15.7	MAR 1970	78	82	57	61	11.2	SSE	66	W	MAY 1946	63	5.7	116	98	151	108	5	59	21	40	16	105	3	971.1

162

- 22.9 to 58.4 cm (9 to 23 in) - yellowish-red silty clay; common fine, faint dark brown and reddish-brown mottles; moderate, very fine, and fine, subangular blocky structure; friable; thin, patchy, clay films; few chert; few iron and manganese concretions; medium acidity.
- 58 to 84 cm (23 to 33 in) - yellowish-red and red silty clay loam; strong fine and very fine, angular and subangular blocky structure; firm; thin, nearly continuous clay films; few chert; few iron and manganese concretions; medium acidity.
- 84 to 114 cm (33 to 45 in) - red and dark red silty clay loam, common, medium and large, distinct brown and pale brown mottles; moderate, fine, angular blocky structure; firm; thick, nearly continuous clay films; few chert; few iron and manganese concretions; medium acidity.
- 114 to 183 cm (45 to 72 in) - dark red cherty clay; common, fine, and medium, distinct light brownish-gray faint yellowish-red and pale brown mottles; moderate fine, angular blocky structure; very firm; thick continuous clay films; 35 to 60 percent chert; common iron and manganese concretions; strongly acidic.

Treated Plot

The soil sampled from the treated plot followed somewhat the profile of Britwater silt loam. The presence of chert, however, at all depths below the first 20 cm (8 in) made sampling extremely difficult - to the point where sufficient sample quantities from the two lowest desired depths, 61 to 91 cm (24 to 36 in) and 91 to 122 cm (36 to 48 in), could not be obtained.

A trench measuring approximately 1.2 x 3.0 x 1.5 m (4 x 10 x 5 ft) deep was dug with a backhoe at the eastern end of the plot adjacent to Section 3 (see Figure IV-1). The following profile was observed:

- 0 to 20 cm (0 to 8 in) - dark gray silt loam; many grass roots; soft and friable; no rocks in ground.
- 20 to 41 cm (8 to 16 in) - dark gray silt loam grading into reddish silt clay loam at the lower depth; estimated 50 percent chert ranging from marble to golf ball size.
- 41 to 61 cm (16 to 24 in) - estimated 85 percent chert ranging from 2.5 to 30 cm (1 to 12 in) in size; yellow silty clay throughout surrounding pieces of chert.
- 61 to 81 cm (24 to 32 in) - estimated 75 percent chert ranging from 2.5 to 30 cm (1 to 12 in) in size; red clayey material surrounding chert.
- 81 to 122 cm (32 to 48 in) - estimated 75 percent large pieces of chert; yellow clay to silty clay surrounding chert.

Control Plot

An examination of the samples taken from the control plot indicated that the soil is of a similar type to that of the treated plot. All of the soil horizons described above for the treated plot are present in the control plot, although significant quantities of chert exist closer to the surface of the control plot. At the south end of the plot the presence of chert in the subsoil occasionally prevented sampling of the mid-subsoil 61 to 81 cm (24 to 32 in) and consistently prevented sampling of the lower subsoil. In the remainder of the control plot, chert was present in quantities sufficient to interfere with sampling only at the lower subsoil horizon.

Texture, pH, and other soil related data are shown in Table 48.

SOURCE AND DESCRIPTION OF SLUDGE

The Southwest Wastewater Treatment Plant (STP), opened in 1958, serves an equivalent population of 164,000 (1976). A second wastewater treatment plant operating in the city of Springfield serves an equivalent population of 19,000 (1976).

As constructed, the STP consists of bar screens followed by an aerated grit removal chamber, preaeration, primary settling, aeration, and final settling. The secondary treatment process utilizes the aeration tanks for nitrification employing the Kraus modification to standard activated sludge. Final discharge of treated effluent is to Wilson Creek.

In 1968, a lagoon was constructed to add tertiary treatment to the system during periods of normal flow and to provide rudimentary treatment of wastewater during periods of peak flow

TABLE 48

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

SPRINGFIELD, MISSOURI

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N (2)	PH (1)	CEC
			SAND	SILT	CLAY					
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	17.0	1.53	12	68	20	0.109	0.61	43.30	7.0	18
20.42 CM	16.1	0.75	10	62	28	0.067	0.36	3.70	7.1	21
41-61 CM	16.6	0.69	11	54	35	0.062	0.10	4.60	7.2	13
61-81 CM	16.8	0.76	9	54	37	0.066	0.10	6.90	7.0	31
81-122 CM	17.1	0.59	11	50	39	0.061	0.10	3.50	5.9	10
CONTROL										
SURFACE	19.1	1.83	8	67	25	0.140	0.56	37.40	6.9	10
20-41 CM	20.2	1.41	8	65	27	0.109	0.60	6.10	7.1	30
41-61 CM	18.3	1.36	8	62	30	0.387	1.20	21.50	7.0	27
61-81 CM	28.4	0.84	12	52	38	0.075	0.1	1.00	6.6	10
81-122 CM	18.8	0.86	13	48	39	0.093	3.40	12.40	6.5	30

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

Table 48 (Continued)

PLOT/ DEPTH	ORG-N	NO3-N	NH4-N(1)
	PERCENT	µG/G	
TREATED			
SURFACE	0.118	0.60	21.4
20-41 CM	0.045	1.20	1.0
41-61 CM	0.043	2.09	3.8
61-81 CM	0.060	3.02	2.0
81-122 CM	0.065	1.32	1.5

TREATED PLOT PROFILE SAMPLES FROM BACK-HOE TRENCH

(1) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

in excess of plant capacity. By 1973, the plant was consistently operating with flows above design capacity. As a result, the principal function of the lagoon became one of primary treatment of sewage flows in excess of design capacity before discharge to Wilson Creek. To facilitate rudimentary treatment in the lagoon, six 14.9 kw (20 hp) floating aerators were added in 1973.

In the spring of 1975 ground was broken for an expansion and modification of the STP. Scheduled completion is for the fall of 1977. When completed, secondary treatment will be accomplished using pure oxygen activated sludge. The system will also include nitrification, gravity sand filtration, and disinfection of the final effluent by ozonation. Vacuum filters will be used to dewater digested sludge prior to application to agricultural land.

The design average daily flow for the STP is 45,400 cu m/day (12 mgd) with a design capacity of 113,600 cu m/day (30 mgd). Presently, however, the average daily flow is approximately 75,700 cu m/day (20 mgd), resulting in only 18,900 cu m/day (5 mgd) receiving rudimentary treatment via the lagoon mentioned above.

The influent to the treatment plant is characteristic of domestic sewage, with an average BOD of 240 mg/l and suspended solids (SS) concentration of 170 mg/l. Current discharge limitations for the plant are 50 mg/l BOD and 70 mg/l SS. The 1975 average effluent BOD and SS concentrations, excluding that portion which receives only rudimentary treatment, are 40 mg/l and 50 mg/l, respectivelyy

An estimated 15 percent of the average daily flow to the STP comes from industrial sources, as shown in Table 49. The principal industrial contributors are food processors and institutions such as hospitals and universities. None of the industrial contributors have average daily flows which vary significantly throughout the year.

Sludge Stabilization and Storage

Sludge from the secondary clarifiers is returned to the primary clarifiers. Sludge drawn from the primaries is partially stabilized in two primary anaerobic digesters, each with 4,160 cu m (1.1 MG) capacity. No chemicals are used throughout the digestion process. The hydraulic design of the sludge digestion system is based on the following retention periods:

. Average (12 mgd) - 20 days
. Maximum (16 mgd) - 16 days
. Peak (20 mgd) - 24 days

Six drying beds, each measuring 30 x 15 x 0.6 m (100 x 50 x 2 ft) provide additional storage capacity. These beds, however, are used infrequently due to the high manual labor costs for handling dried sludge.

On September 19, 1975, a Phase I grab sample of stabilized sludge was obtained from the truck loading port of the secondary digester. This sample was analyzed by conventional atomic absorption techniques. This data and three other analyses per-

169

TABLE 49

SPRINGFIELD, MISSOURI - INDUSTRIAL FLOWS

Source	Average flow (cu m/day)
American Laundry Co.	210
Cox, Lester E., Medical Center	880
Drury College	420
Empire Foods, Inc.	180
Evangel College	420
Foremost Foods Co., Dairy Div.	660
French, R. T., Co.	300
Kraft Foods Co.	670
Kraft Foods Consolidated Ind.	1270
Lily, Div. of Owens-Illinois	450
M.F.A., Packing Division	350
Mid-America Dairymen, Inc.	1070
St. John's Hospital	690
St. Louis-San Francisco Rw. Co.	390
Southwest Missouri State Univ.	1320
Syntex Agribusiness, Inc.	350
Hiland Dairy, Inc.	700
Total	10,330

formed at the STP laboratory are presented in Table 50. Lead shows the greatest fluctuation, with a range from 707 to 1940 μg/g.

Disposal of Sewage Sludge

Records of total quantities of sludge generated by the STP from 1958 to 1962 are not available. However, records have been maintained since 1963. The rate of application has been fairly constant on the study site.

Spreading and hauling were relatively uniform throughout 1975 as shown on Table 51. Assuming 3 percent solids (STP analytical data) an annual total of 1,815 dry m tons (2,000 dry tons) is generated.

Essentially, all of the sludge generated by the treatment plant is spread on agricultural land. A small percentage is spread on drying beds and subsequently used by local residents and the local golf course as a fertilizer and soil conditioner. Two trucks are used continuously to haul sludge from the sewage treatment plant. Each is fitted with an 11.4 cu m (3,000 gal) capacity tank and a spreading bar for distribution of sludge by gravity. At the farm the truck drives across the field with the sludge discharging through the spreader pipe. Each tank covers an area approximately 550 m (1,800 ft) long and 2.5 m (8 ft) wide.

When the plant first opened in 1958, the operators experienced difficulty locating farmers who were willing to have sludge applied to their land. Several farmers were eventually

TABLE 50

SPRINGFIELD, MISSOURI - STABILIZED LIQUID SLUDGE ANALYSES[1]

Parameter	Concentration Test A[2] µg/g	 Test B[2] µg/g	 Test C[2] µg/g	 Test D[3] µg/g
Cd	32	43	58	54
Cu	816	532	606	232
Ni				672
Pb	1923	1255	707	1940
Zn	4710	3760	3990	440
Cr	1170	1310	2020	
Moisture (%)				98.5

---

[1] HNO_3-$HClO_4$ digestions; Data expressed on an oven dry weight basis

[2] Springfield STP Lab, dates unknown

[3] Phase I stabilized sludge sample, Sept. 19, 1975

TABLE 51

SPRINGFIELD, MISSOURI - LIQUID SLUDGE HAULING QUANTITIES (cu m)

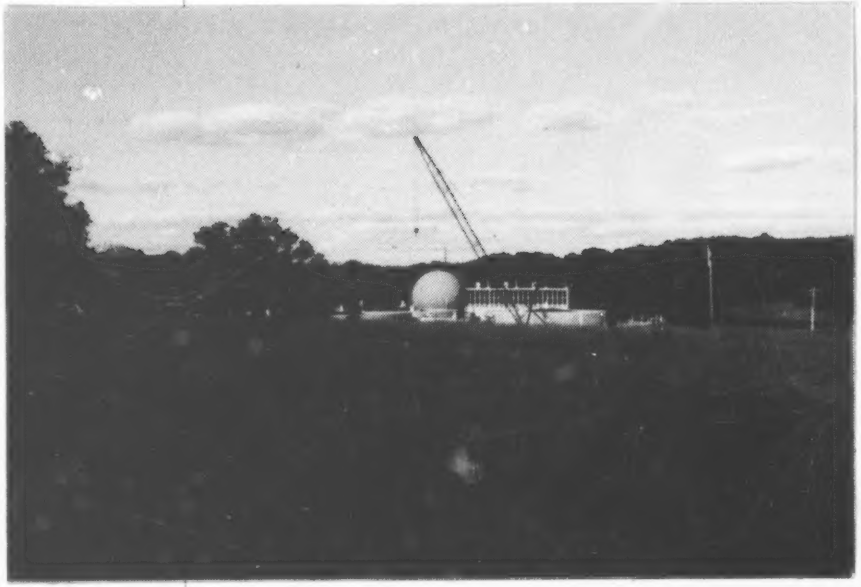
Month	1975
Jan.	2270
Feb.	11400
Mar.	7950
Apr.	2650
May	5300
June	2650
July	6800
Aug.	3800
Sept.	3400
Oct.	4540
Nov.	4920
Dec.	4920
Total	60600

persuaded, however, to use sludge, on a trial basis, as a fertilizer supplement. After several years the farmers were convinced that these applications were beneficial. Local demand for the sludge has increased ever since. At the present time demand exceeds supply. The result is that sludge is limited to farms within a radius of 6.7 km (4 mi) from the STP.

The sewage treatment plant maintains a list of farmers to receive the sludge. Each farmer is alloted an equal amount of sludge to cover 32.4 ha (80 acres). Assuming the farmer will accept the alloted amount, the sludge is spread. If the farmer declines, the next name on the list is contacted and sludge delivery begins at that farm. When the last name on the list is reached, the rotation begins again with the first farm. During non-haul periods sludge is stored in the digesters.

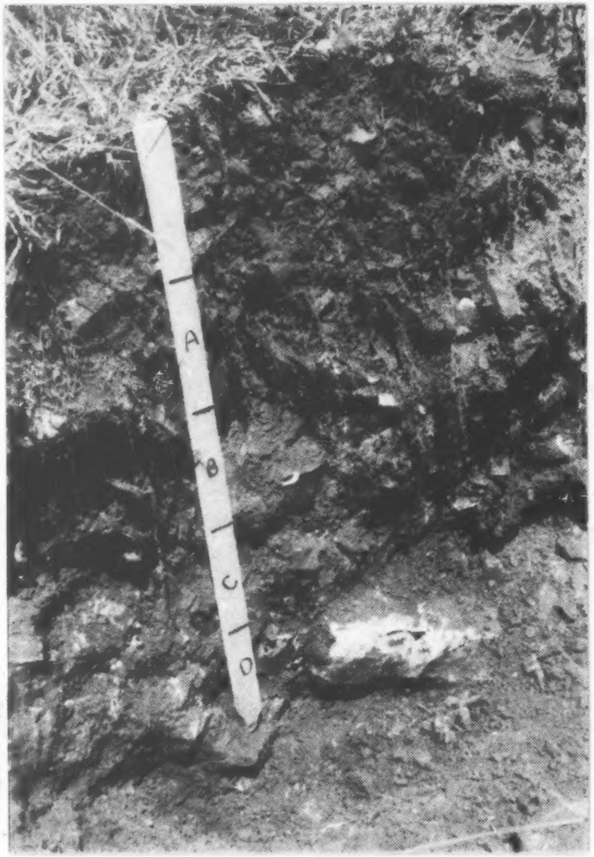
At the time of sampling, interviews with the farmer of the treated plot and personnel at the STP indicated no known aesthetic or environmental problems associated with the sludge spreading program. One potential problem, however, was discussed which dealt with the pond near the treated field (See Figure 36). The natural drainage pattern of the treated field is toward the pond which supplies drinking water for livestock. Although water from the pond has never been analyzed, it is conceivable that runoff from heavy rains could contain dissolved constituents from prior sludge applications.

Photographs 16 through 19 show respectively the treated plot, fescue on the treated plot, the backhoe exposure on the treated plot, and the control plot.



Photograph 16
Treated Field

Photograph 17
Fescue, Treated Plot



Photograph 18
Backhoe Trench, Treated Field

Photograph 19
Control Field

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

The Department of Public Works, the [illegible]ty Health Department, the Missouri State Department of Na[illegible] Resources, the local newspaper, and the STP superintendent were contacted to determine public attitudes toward the use of sewage sludge as a soil amendment.

When questioned concerning the public reaction to the land spreading of sludge, the Public Works Department stated they had never been questioned or challenged on this method of sludge disposal. A representative of the Health Department stated that the department believes sludge spreading to be a desirable and acceptable method of sludge disposal. A telephone interview with a representative of the Department of Natural Resources indicated that they were aware of the sludge spreading practice and were in the process of preparing guidelines for all such sludge applications in the state. Contact with the editor of the local newspaper indicated that no articles relative to sludge disposal had ever been written.

Despite this lack of publicity, local citizens other than farmers are interested in obtaining sludge. The STP personnel report that they receive several calls daily from individuals who wish to obtain sludge from the drying beds for use on their lawns or gardens. Before construction of the sewage treatment expansion began, local citizens were usually allowed entrance to remove sludge from the drying beds. Because of the construction activities, however, this is no longer possible; and it is necessary for a plant employee to clean the beds and pile the dried sludge in a location more easily accessible to the public. As a result of greater labor costs required by this procedure compared to spreading sludge on surrounding farms, the availability of sludge for local citizens is currently limited.

Some odor complaints from neighboring farms have been received. However, these complaints are thought to result for the most part from jealousy on the part of farmers who have not been able to receive sludge from the treatment plant.

Interviews with local Soil Conservation Service personnel indicated their awareness and acceptance of the sludge spreading practices. However, it was noted that the limestone bedrock formations in southwestern Missouri are highly fractured. As a result, contaminants may reach groundwater in some locations. Additional study and monitoring were recommended.

STATE AND LOCAL REGULATIONS

Representatives of the Solid Waste and Water Resources Divisions of the Missouri Department of Natural Resources indicated that there are no regulations or requirements pertaining to the use of sewage sludge on agricultural lands. A disposal permit is required if wastewater sludge is to be placed in a landfill but not if it is spread on agricultural land. The Solid Waste Division is currently planning to develop guidelines for the application of sludge to agricultural land.

In a separate interview, a representative of the Health Department also indicated that there were no regulations governing disposal of sludge to agricultural lands, and that the department was aware of the current sludge spreading practice.

ECONOMICS

Equipment Description and Cost

A cost of approximately $10,000 was incurred in 1958 for the installation of sludge spreading equipment. At that time pipes were installed from the digesters to a location convenient for truck loading. Associated with these costs were labor and materials for electrical controls to operate the sludge pumps.

Two 11.4 cu m (3,000 gal) tank trucks are used to spread the sludge. One is a 1969 Chevrolet purchased new for $12,000; the other is a 1971 Chevrolet purchased new for $18,000. The tanks, manufactured by Acro Tank in Springfield, Missouri, were purchased for $2,800 each to coincide with delivery of the trucks.

Operation and maintenance costs for the trucks are estimated by plant personnel to be $0.25 per mile. Total combined annual mileage for both vehicles is approximately 25,000.

Two plant employees are assigned essentially full time to haul liquid sludge. The basic salary for these employees is $8,000 per year, plus 25 percent fringe benefits. Additional labor is needed for handling the bed dried sludge. An "average" year was estimated to require approximately 60 man-days of manual labor (shoveling, raking, etc.). Table 52 provides an analysis of the cost of spreading liquid sludge.

SAMPLING AND ANALYSIS

Sludge

On May 17 and September 7, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the secondary sludge digester.

Soil

On May 17 and 18, 1976, surface and subsurface soil samples were obtained from both the treated and control plots. As shown in Figures 36 and 37 the treated and control plots were divided into five sections. Twenty core samples from the surface 0 to 20 cm (0 to 8 in) were collected with a 2.5 cm (1 in) diameter stainless steel split tube sampler. Dead plant debris on the top portion of each core was discarded prior to placing the soil core in a sample bag.

Subsurface soil samples were obtained with an 8 cm (3 in) diameter bucket auger. At the treated plot the top 20 cm (8 in) of soil were discarded from the bucket auger. Samples obtained from the depths between 20 and 41 cm (8 and 16 in) were labeled horizon A; 41 to 61 cm (16 to 24 in) horizon B; 61 to 81 cm (24 to 32 in) horizon C; and 81 to 122 cm (32 to 48 in) horizon D. Chert in the subsoil prevented the sampling of a D-horizon sample from Section 3.

As indicated in Figure 36 a trench approximately 18 m (20 yd) from the south end of Section 3 and approximately 1.2

TABLE 52

COST FOR DISPOSAL OF LIQUID SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation[1]			
1969 Chevrolet Truck: $12,000			$ 2,036
1971 Chevrolet Truck: $18,000			3,054
2 3,000-gal Tanks: $5,600			950
Stationary Equipment Depreciation[2]			
Total Annual Capital Cost			$ 6,040
Annual Operating Cost			
Personnel	Hourly Rate	% Time Worked	
2 Operators	$4	100	$16,000
Fringe Benefits (25 percent)			4,000
Vehicle Maintenance and Operation			6,250
Total Annual Operating Cost			$26,250
Total Annual Capital and Operating Cost			32,290
10 Percent Contingency Factor[3]			3,229
Total Annual Cost (Average)			$35,519

$$\frac{\text{Total Annual Cost (Avg.)}}{\text{Total Sludge Hauled Annually}} = \frac{\$35,519}{\text{2000 dry tons}} = \frac{\$19.58/\text{dry m ton}}{(\$17.76/\text{dry ton})}$$

---

[1] Vehicles were fully depreciated over 8 years assuming 8 percent interest, equivalent to $169.68 per $1,000 annually.

[2] Stationary equipment was fully depreciated over 8 years assuming 8 percent interest, equivalent to $145.56 per $1,000 annually.

[3] A 10 percent contingency factor is added to cover such items as administrative overhead.

x 3.0 x 1.5 m (4 x 10 x 5 ft) deep was dug with a backhoe (see Photograph 17) to visually examine the various soil horizons and obtain additional soil samples. Based on the difficulty of sampling, the control plot was estimated to have a greater percentage of limestone and chert from 46 to 122 cm (18 to 48 in) than the treated plot. Soil samples from the backhoe trench were used to augment the composites at the C and D levels.

Both surface and subsurface soil samples at the control plot were obtained in exactly the same manner as those at the treated plot.

At the control plot, 20 holes were initiated with the bucket auger in Section 1, but due to chert, only two penetrated to the C-horizon. Consequently, only two subsamples comprise the composite for C-horizon in Section 1. In Section 2 twenty holes were initiated with only three penetrating into the C-horizon. Here again, no D-horizon sample was obtained; consequently only three subsamples comprise the C-horizon composite. In Sections 3, 4, and 5 chert was found in the C- and D-horizons, but sufficient samples were obtained.

Plants

Plant samples from the treated and control plots were taken in identical manners. Samples of the grasses were sheared approximately 13 cm (5 in) from the ground with each sample containing approximately 100 individual blades ranging in length from 15 to 46 cm (6 to 18 in). Approximately 20 such samples were obtained from each section.

Tables 53 through 61 present the following:

Table	Description
53	Chemical Characterization of Stabilized Sludges
54	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
55	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils - Treated Plot Profile Samples from Back-Hoe Trench
56	Total Metal Concentrations in Individual Subsurface Samples
57	Molybdenum in Composite Plants and Soils
58	Metal Concentrations in Surface Soils
59	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
60	Parasites in Sludges, Soils, and Plants
61	Concentration of Microbes in Sludges, Soils, and Plants

Figures 38 to 47 present particle size analyses of the various soil composites by depth.

TABLE 53

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM SPRINGFIELD, MISSOURI

	5/17/76	9/7/76	Average
Volatile Solids (%)	60.37	58.04	59.2
NO_3 - N	100	<2.73	51.4
NH_4 - N	58923	24691	41807
Organic N	53154	32818	42986
P	8808	26000	17404
K	7154	3545	5350
Na	10692	5272	7982
Ca	66308	52000	59154
Mg	7269	5409	6339
SO_4	<154	68.2	111
Cl	669	9227	4948
Ag	1.00	0.91	0.95
As	9.23	3.15	6.21
B	60.0	20.9	40.5
Cd	55.4	56.8	56.1
Cr	2231	2627	2429
Co	15.4	2.73	9.07
Cu	786	859	823
Fe	13462	13545	13504
Hg	7.69	13.5	10.6
Mn	388	509	449
Mo	37.7	49.1	43.4
Ni	336	268	302
Pb	6.92	295	151
Se	8.15	8.18	8.17
Zn	3246	3364	3305
H_2O (%)	98.7	97.8	98.3
pH	8.2	8.5	

All units in μg/g (unless otherwise noted)

All data expressed on oven dry weight basis

TABLE 54

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

SPRINGFIELD, MISSOURI

PLOT/ DEPTH:	TOTAL METALS (2)					DTPA EXTRACTABLES			
	CD	CU	NI	ZN	PB	CD	CU	NI	ZN
	μ G/G					μ G/G			
TREATED									
SURFACE	1.17	10.5	28.9	108	40.20	0.38	7.07	3.18	36.6
20-41 CM.	0.77	13.1	28.2	41.8	21.40	0.11	1.80	1.62	3.03
41-61 CM.	0.82	15.7	47.6	48.8	25.80	0.07	1.47	1.56	2.00
61-81 CM.	0.83	20.0	38.7	52.9	28.00	0.07	1.87	1.57	2.30
81-122 CM.	0.77	16.1	35.8	57.6	25.10	0.06	1.12	1.10	1.00
CONTROL									
SURFACE	0.73	23.6	19.9	36.8	34.00	0.11	7.35	1.49	1.79
20-41 CM.	0.68	14.3	22.7	34.8	24.10	0.09	2.87	1.11	2.78
41-61 CM.	0.70	12.0	24.4	39.2	22.10	0.07	1.32	0.95	1.42
61-81 CM.	0.82	13.2	28.8	45.7	20.60	0.06	0.98	0.96	0.68
81-122 CM.	0.89	15.0	34.4	48.0	26.10	0.06	1.36	0.97	1.13

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 55

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

SPRINGFIELD, MISSOURI

PLOT/ DEPTH:	TOTAL METALS (2) CD	CU	NI	ZN	PB	DTPA EXTRACTABLES CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	1.31	24.7	35.2	127.0	45.7	0.53	8.06	6.25	52.5
20-41 CM.	2.00	28.1	79.2	51.4	40.9	0.16	1.80	2.66	1.87
41-61 CM.	1.36	30.0	53.0	59.5	32.1	0.13	0.51	2.51	1.42
61-81 CM.	1.09	28.2	47.5	63.5	23.9	0.07	0.86	1.11	1.24
81-122 CM.	1.09	18.7	57.8	104.0	30.4	0.06	0.43	0.93	0.50

TREATED PLOT PROFILE SAMPLES FROM BACK-HOE TRENCH

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 56

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES (1)

SPRINGFIELD, MISSOURI

SECTION/ DEPTH	TREATED				CONTROL			
	CD	CU	NI	ZN	CD	CU	NI	ZN
	µG/G				µG/G			
SECTION 1								
20-41 CM.	0.78	13.7	24.7	47.0	0.74	14.4	22.2	37.3
41-61 CM.	0.80	14.2	29.2	52.0	0.75	12.6	27.1	44.0
61-81 CM.	0.90	15.9	34.0	51.0	0.71	13.6	34.4	48.8
81-122 CM.	0.77	17.2	31.5	57.1	0.94	14.8	34.7	46.7
SECTION 2								
20-41 CM.	0.73	12.7	24.1	44.6	0.66	14.7	19.8	30.8
41-61 CM.	0.72	14.0	25.0	49.3	0.96	13.9	28.8	45.6
61-81 CM.	0.78	21.3	32.8	50.5	0.92	15.2	33.7	57.2
81-122 CM.	0.88	21.8	41.9	57.6	0.92	20.0	39.0	65.1
SECTION 3								
20-41 CM.	0.70	12.0	23.0	47.2	0.62	13.2	21.8	36.2
41-61 CM.	0.66	16.5	27.1	49.2	0.56	11.9	21.2	38.7
61-81 CM.	0.81	22.2	39.0	56.1	0.86	13.5	28.2	49.9
81-122 CM.	0.0	0.0	0.0	0.0	0.74	15.6	34.0	59.4
SECTION 4								
20-41 CM.	0.67	12.1	23.0	45.9	0.69	19.9	19.9	37.1
41-61 CM.	0.80	14.3	28.5	54.4	0.66	12.5	21.2	39.2
61-81 CM.	0.88	6.7	3.05	6.8	0.87	14.0	30.6	50.0
81-122 CM.	0.79	17.6	36.4	57.6	0.86	14.2	33.2	55.0
SECTION 5								
20-41 CM.	0.67	11.4	20.9	40.4	0.65	13.1	20.9	36.9
41-61 CM.	0.70	12.3	23.5	49.2	0.74	13.8	21.6	43.6
61-81 CM.	0.76	15.4	28.4	58.6	0.80	13.3	28.4	49.5
81-122 CM.	0.81	15.4	31.4	54.7	0.91	14.5	32.8	55.7

(1) HNO_3-$HCLO_4$ DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 57

MOLYBDENUM IN COMPOSITE LAND AND SOILS

Springfield, Missouri

	Treated Plot	Control Plot
	µg/g	
Plant (fescue)	0.84	0.67
Soil (depth in cm)		
0-20	1.90	2.00
20-41	2.58	2.17
41-61	1.79	1.90
61-81	2.65	2.99
81-122	2.93	3.26

TABLE 58

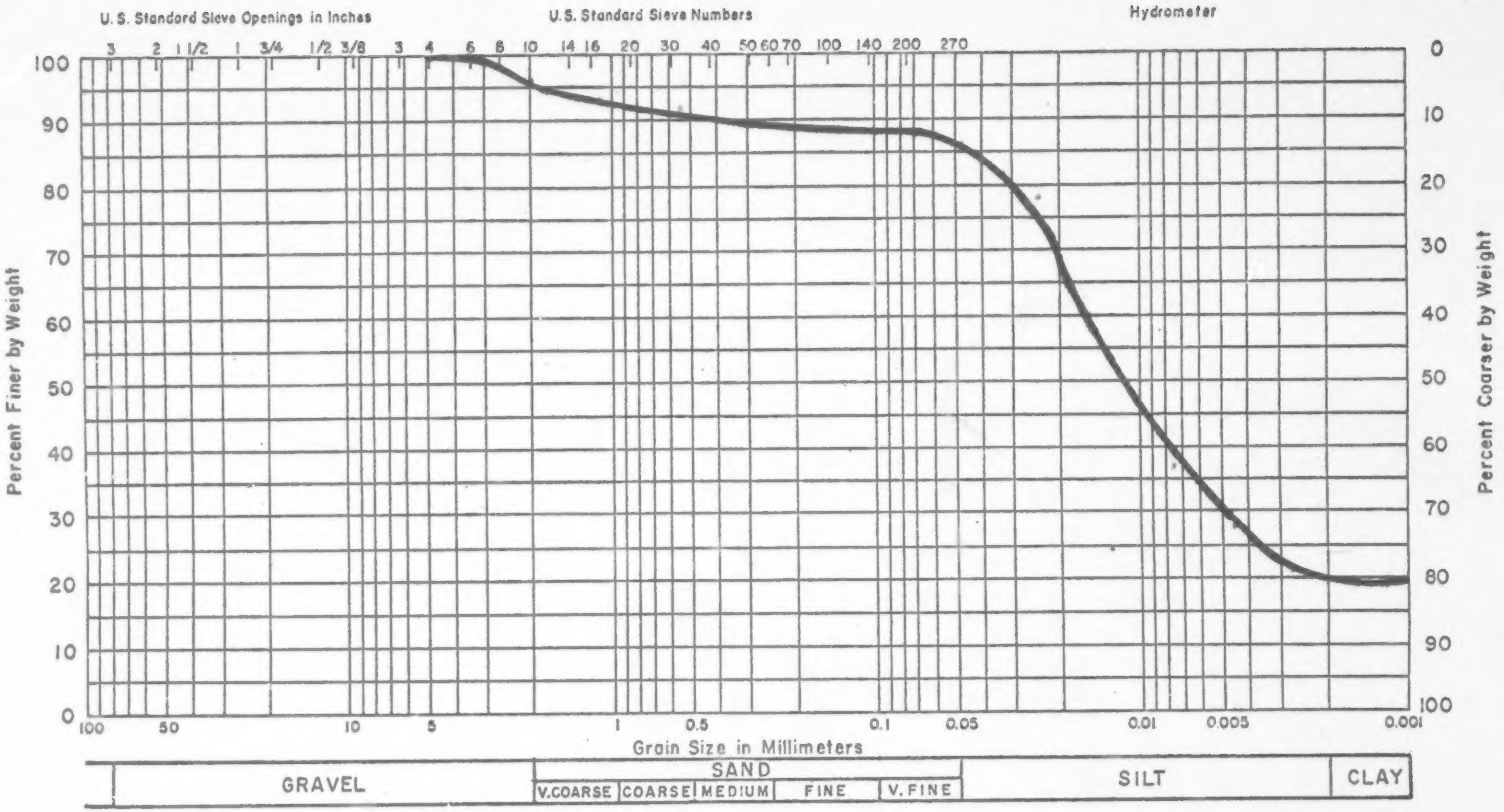
METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS[(1)]

SPRINGFIELD, MISSOURI

SAMPLE	SURFACE SOIL					PLANT					
	CD	CU	NI	ZN	PB(2)	CD	CU	NI	ZN	PB(2)	ORG-N(2)
	µG/G					µG/G					
TREATED											
COMPOSITE	1.17	10.5	28.9	108	40.2	0.25	4.79	4.27	26.0	2.71	1.56
SECTION 1	1.27	22.5	39.8	111		0.36	4.22	4.15	28.4		
SECTION 2	1.16	19.6	29.8	102		0.41	4.68	4.71	32.8		
SECTION 3	1.12	19.9	27.8	104		0.32	4.76	4.21	32.8		
SECTION 4	1.05	19.5	26.7	104		0.33	4.50	3.76	28.7		
SECTION 5	1.02	24.0	26.7	95		0.29	4.97	5.05	33.7		
MEAN	1.12	21.1	30.2	103		0.34	4.63	4.38	31.3		
STD. DEV.	0.10	2.04	5.54	5.58		0.05	0.28	0.51	2.52		
CONTROL											
COMPOSITE	0.73	23.6	19.9	36.8	34.0	0.29	5.79	3.96	23.4	5.60	2.29
SECTION 1	0.72	19.6	21.2	38.0		0.27	5.12	3.76	23.8		
SECTION 2	0.74	23.0	23.1	39.1		1.03	5.12	3.59	24.1		
SECTION 3	0.73	32.4	21.9	39.0		0.36	5.22	3.59	26.0		
SECTION 4	0.85	25.0	22.0	38.8		0.24	5.20	3.25	24.5		
SECTION 5	0.72	26.1	21.0	41.5		0.25	5.61	3.37	24.9		
MEAN	0.75	25.2	21.8	39.3		0.43	5.25	3.51	24.7		
STD. DEV.	0.06	4.71	0.83	1.31		0.34	0.20	0.20	0.86		

(1) ALL DATA EXPRESSED ON OVEN-DRY WEIGHT BASIS.

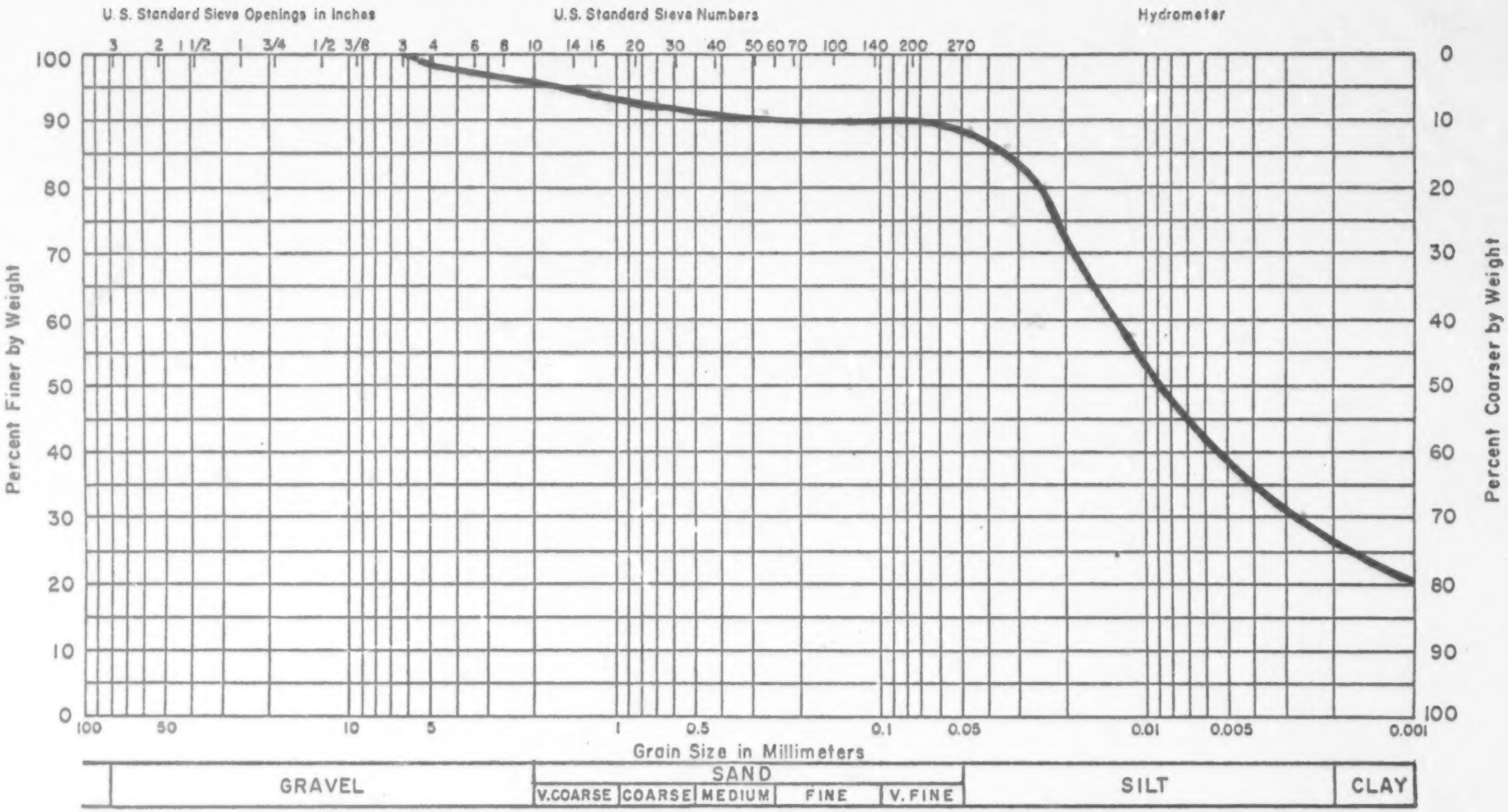
(2) ANALYSIS ON COMPOSITE ONLY.



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
705	Springfield	12	68	20	Silt Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

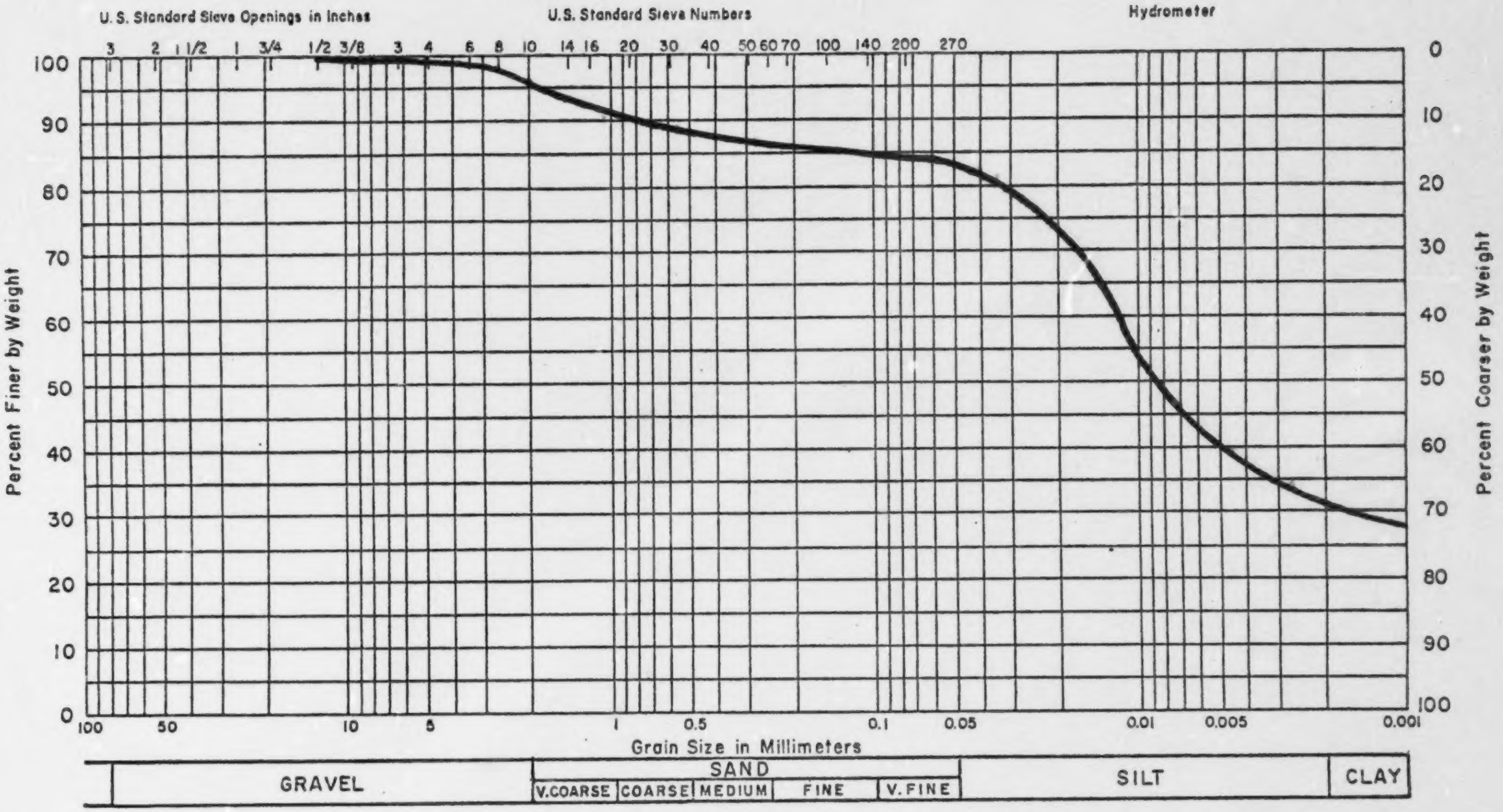
Figure 38 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
711	Springfield	10	62	23	Silty Clay Loam
	Treated				
	20-41 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

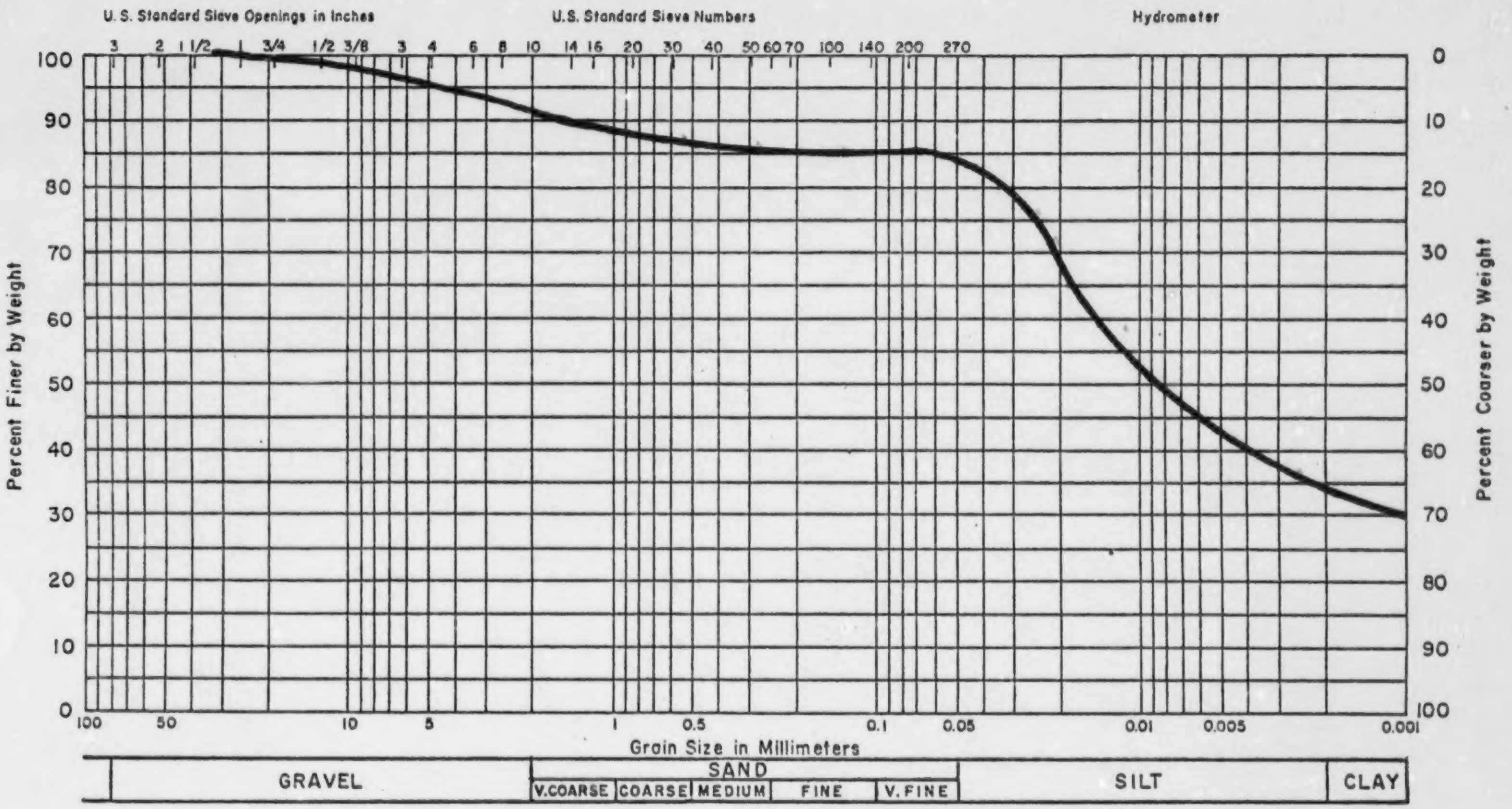
Figure 39 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
717	Springfield	11	54	35	Silty Clay Loam
	Treated				
	41-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

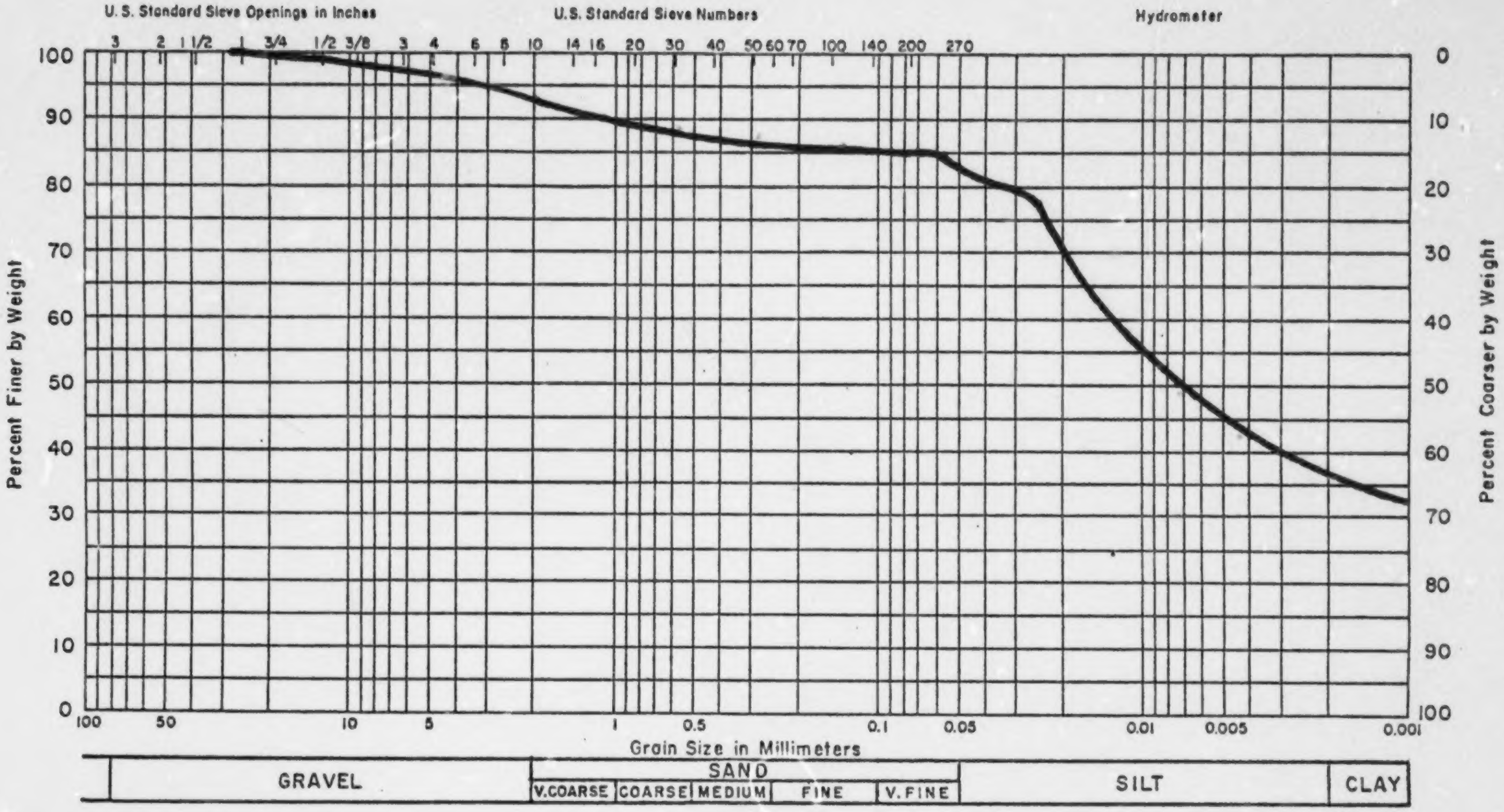
Figure 40 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
723	Springfield	9	54	37	Silty Clay Loam
	Treated				
	61-81 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

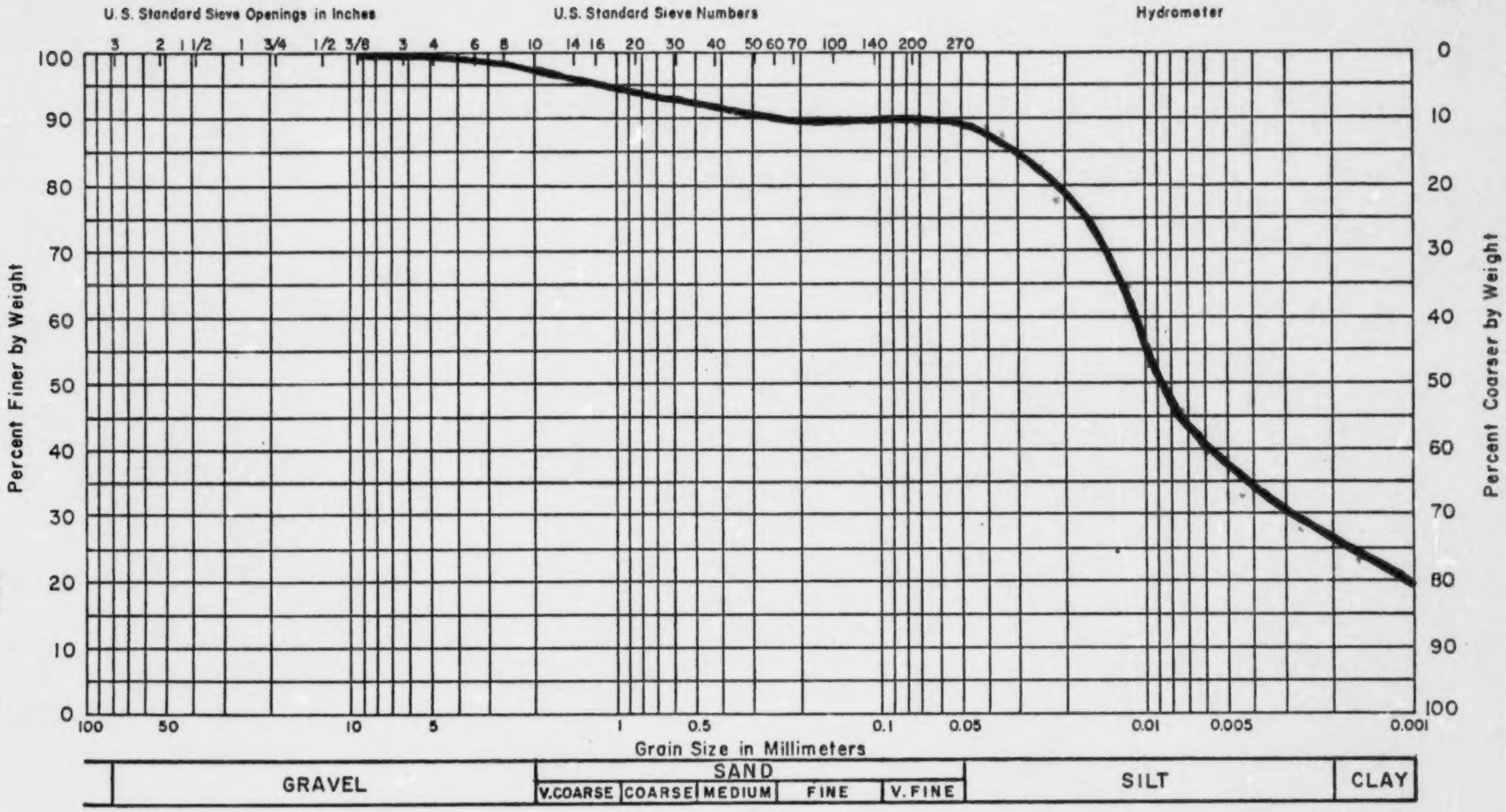
Figure 41 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
728	Springfield	11	50	39	Silty Clay Loam
	Treated				
	81-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

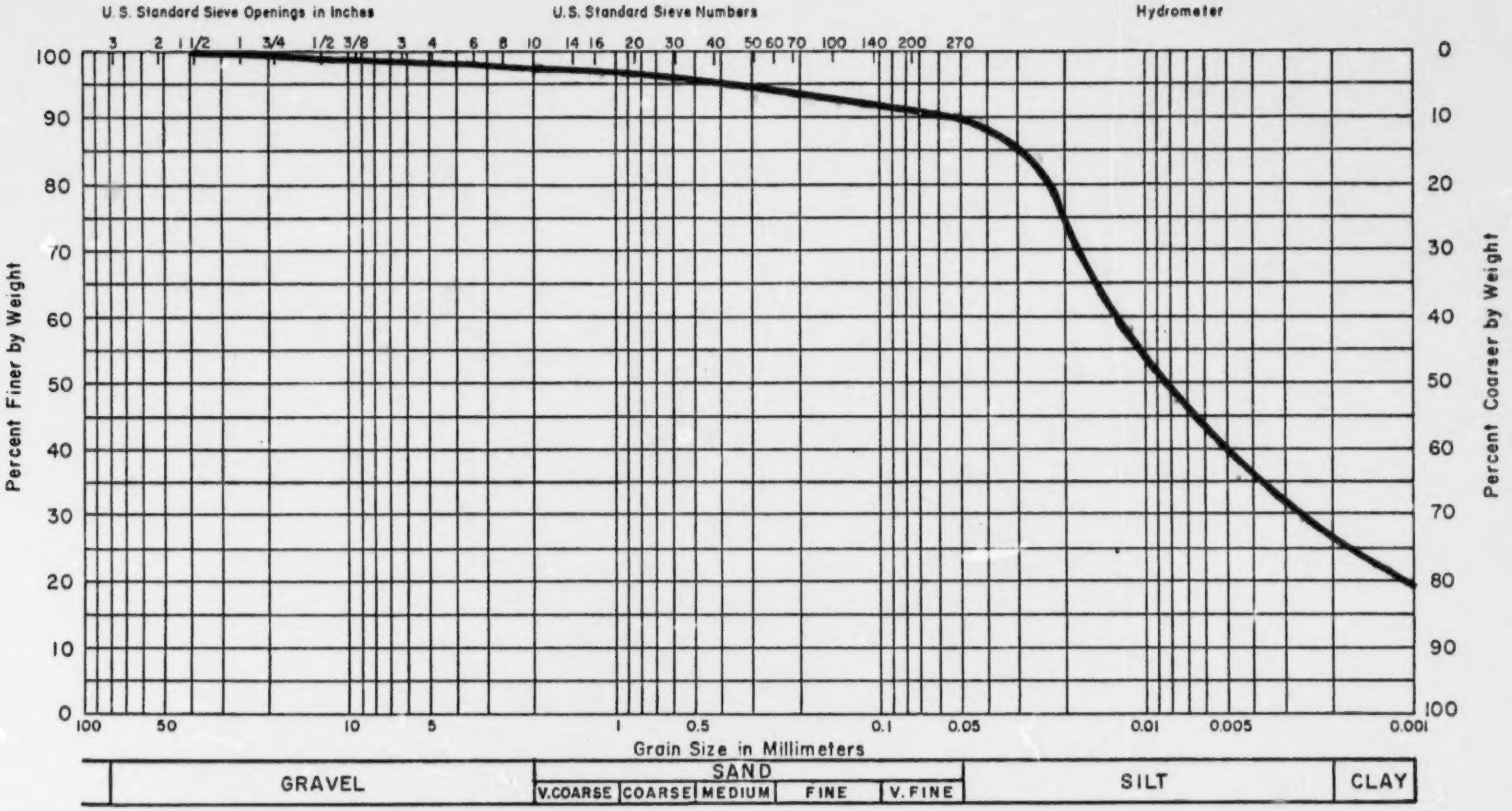
Figure 42 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
675	Springfield	8	67	25	Silt Loam
	Control				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

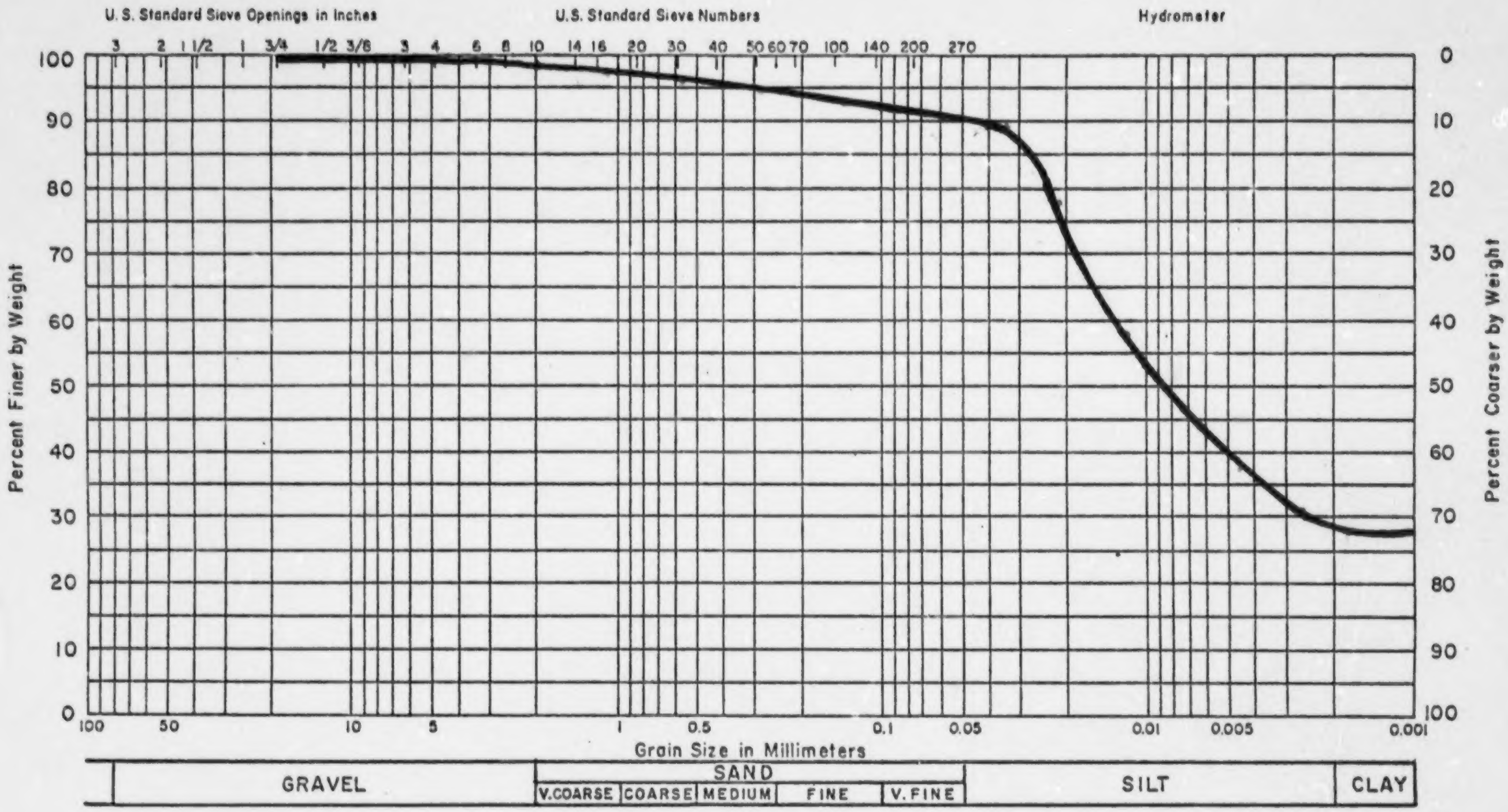
Figure 43 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
681	Springfield	8	65	27	Silty Clay Loam/Silt Loam
	Control				
	20-41 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

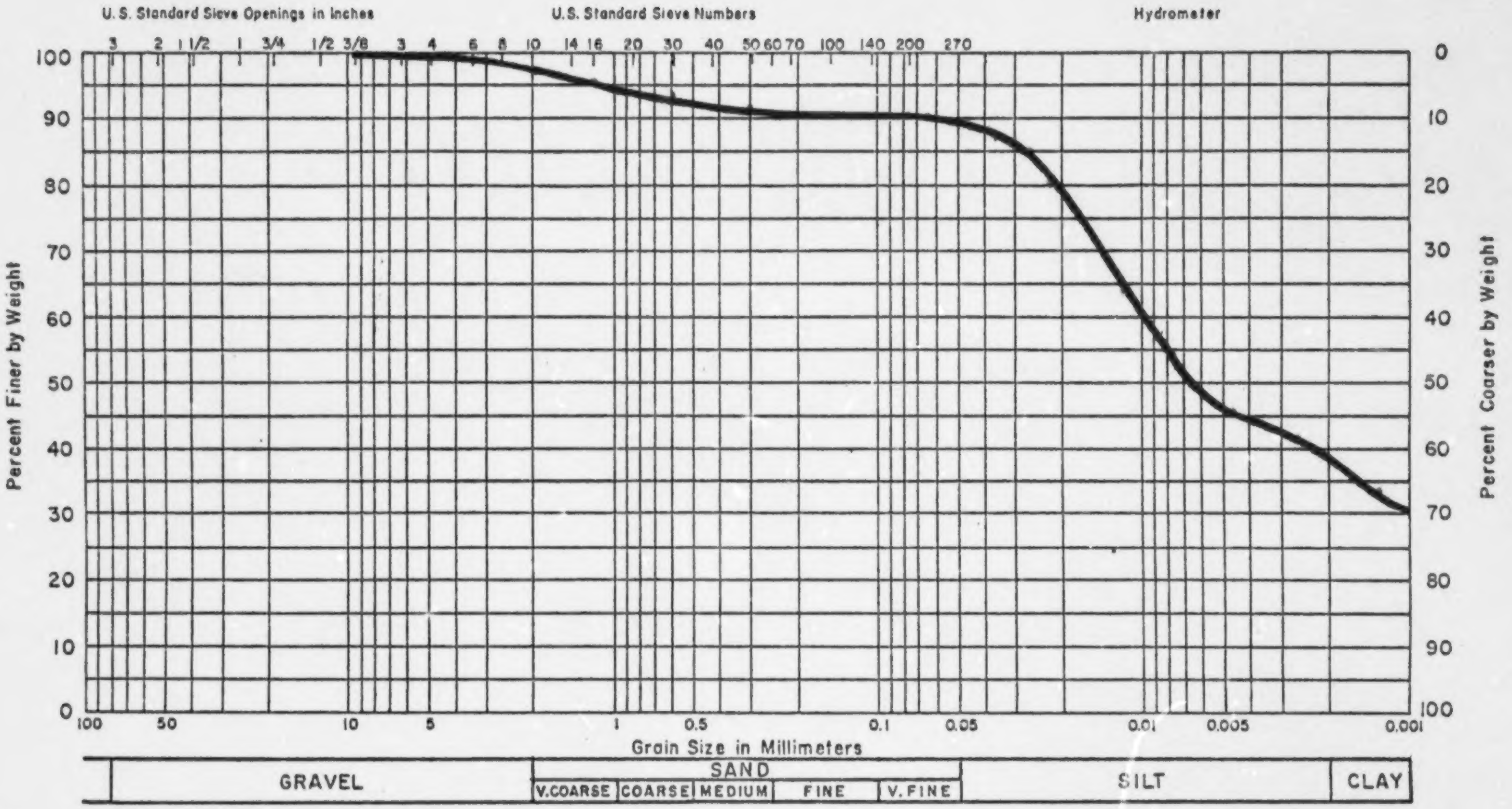
Figure 44 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
687	Springfield	8	62	30	Silty Clay Loam
	Control				
	41-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

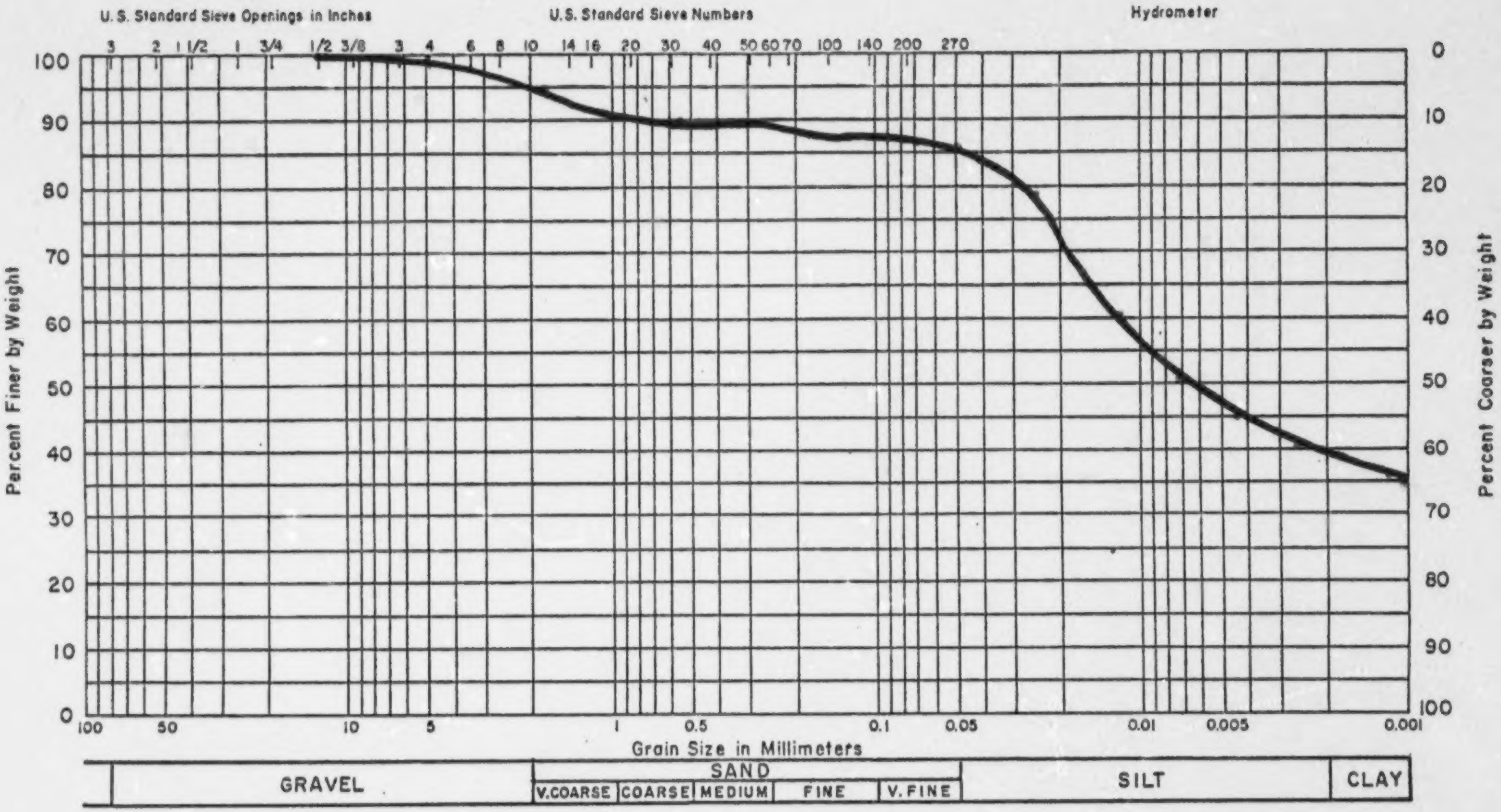
Figure 45 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
693	Springfield	12	52	36	Silty Clay Loam
	Control				
	61-81 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 46 Springfield, MO, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
699	Springfield	13	48	39	Silty Clay/Silty Clay Loam
	Control				
	81-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 47 Springfield, MO, Particle Size Analysis

TABLE 59

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

SPRINGFIELD, MISSOURI

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . μg/kg	. . . .	
Soil			
Surface Composites	0.08	0.12	DDT
	<0.02[1]	<0.02	DIELDRIN
	<0.02	<1	PCB 1221
	73	1	PCB 1248
Plant			
Composites	<0.01	<0.02	DDT
	<0.02	<0.02	DIELDRIN
	0.16		PCB 1221
	0.11		PCB 1248
	(5/17/76)	(9/7/76)	
Stabilized Sludge	1.54	<0.26	DDT
	114	<0.09	DIELDRIN
	<.01	<.01	PCB 1221
	2846	5087	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 60

PARASITES IN SLUDGES, SOILS, AND PLANTS

SPRINGFIELD, MISSOURI

Sample Description	Results
Sludge	
Raw (5/17/76)	Toxocara canis - < 50 ova/gram
Raw (9/7/76)	Toxocara canis - < 50 ova/gram
Stabilized (5/17/76)	Negative
Stabilized (9/7/76)	Ascaris lumbricoides and toxocara canis - <50 ova/gram
Plant	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
20-41 cm	Negative
41-61 cm	Negative
61-81 cm	Negative
81-122 cm	Negative
Soils - Control Composites	
Surface	Negative
20-41 cm	Negative
41-61 cm	Negative
61-81 cm	Negative
81-122 cm	Negative

TABLE 61

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
SPRINGFIELD, MISSOURI

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 5/17	$6.5x10^6$	>1.3	+	+	+	ND	+	-	-	1,100	+	+	+	$1.2x10^5$	+	+	+
Raw 9/7	$7.5x10^9$	ND	+	-	-	ND	+	-	-	300	+	+	+	$4.8x10^8$	+	+	+
Stab 5/17	$7.27x10^{10}$	ND	+	-	-	ND	+	-	-	780	+	+	+	$8\ x10^4$	+	+	+
Stab 9/7	$9.0\ x10^6$	ND	+	+	-	ND	+	-	-	933	+	+	+	$4.4x10^8$	+	+	+
Plants																	
Treated	$4.18x10^9$	ND	+	-	-	ND	+	-	-	ND	+	-	-	19,000	+	+	+
Control	$3.30x10^9$	ND	+	-	-	ND	+	-	-	ND	+	-	-	830	+	+	+

[1] All results expressed on a dry weight basis.

*Values expressed as a power of 10 (i.e., 10^4).

**Observations reported as + or -.

ND = none detected.

TABLE 61 (Continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites	(10^6)																
Surface	11.3	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	-	-
20-41 cm	6.5	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	-	-
41-61 cm	5.42	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	+	-
61-81 cm	3.95	ND	+	-	-	ND	+	-	-	ND	+	-	-	5	+	+	+
81-122 cm	4.29	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	-	-
Soils - Control Composites																	
Surface	10.6	ND	+	-	-	ND	+	-	-	5.1	+	+	+	303	+	+	+
20-41 cm	5.25	ND	+	-	-	ND	+	-	-	ND	+	-	-	5	+	+	+
41-61 cm	5.63	ND	+	-	-	ND	+	-	-	ND	+	-	-	54	+	+	+
61-81 cm	7.88	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	-	-
81-122 cm	2.00	ND	+	-	-	ND	+	-	-	ND	+	-	-	ND	+	-	-

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER V

CHIPPEWA FALLS, WISCONSIN

SITE DESCRIPTION

Location

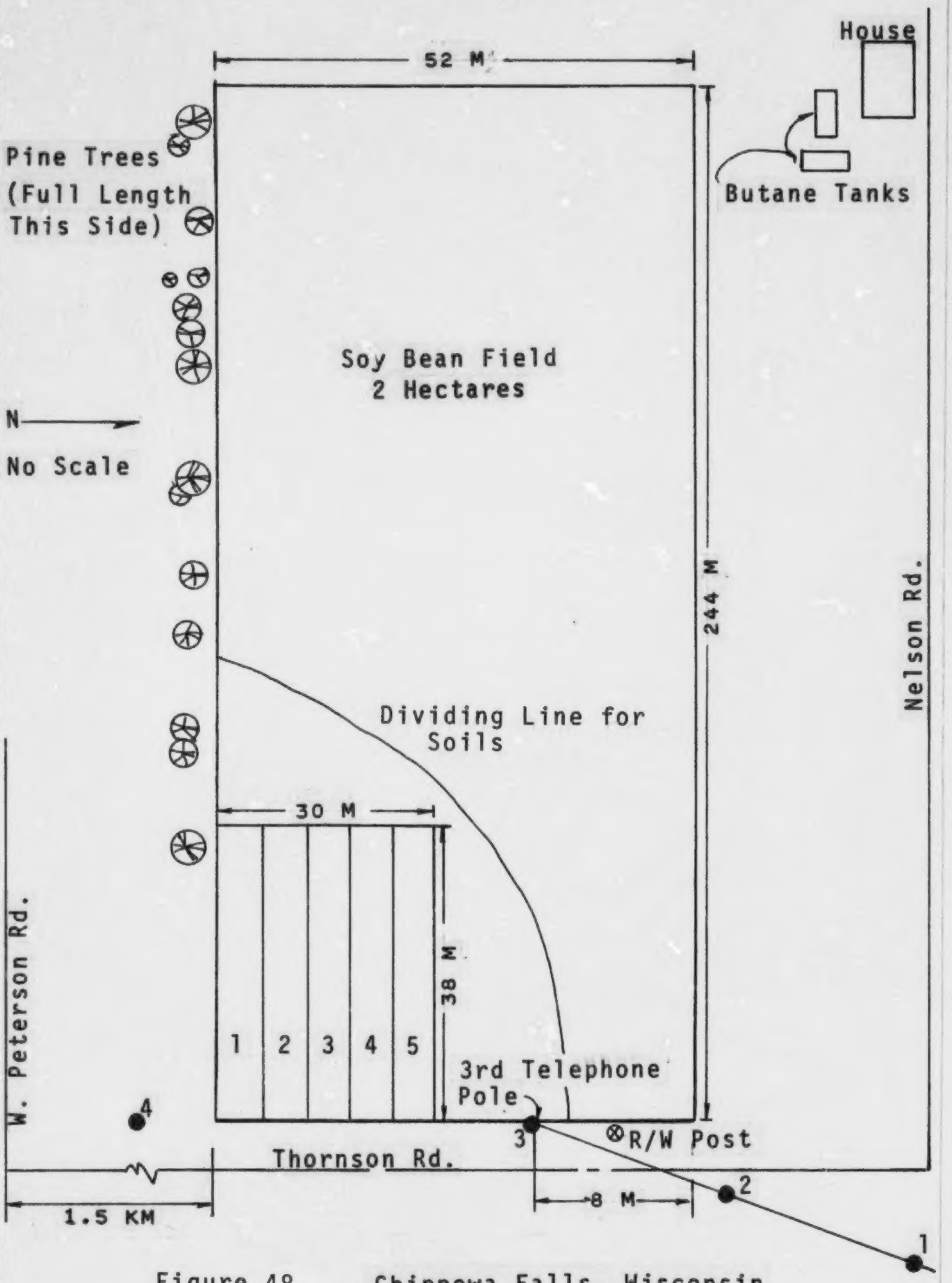
This study site is located approximately 8.0 km (5 mi) southwest of downtown Chippewa Falls, a small, rural town in northwest Wisconsin. Chippewa Falls is about 19 km (12 mi) northwest of Eau Claire and about 515 km (320 mi) northwest of Milwaukee.

The treated (sludged) and control plots are located on a single 72.9 ha (180 acre) farm and are separated by a distance of approximately 1 km (0.5 mi). The Chippewa Falls Wastewater Treatment Plant (STP) is approximately 8.0 km (5 mi) north of the study site.

Physical Condition

The fields in which the treated and control plots are located are planted in soybeans (*Glycine soja*) and are located on level terrain. Figures 48 and 49 show the locations of the treated and control plots within their respective fields. Adjacent farm properties were observed to be in corn, hay and oats.

The treated plot is located within a 2.0 ha (5 acre) field and measures approximately 31 x 38 m (100 x 125 ft). This area was selected for sampling because, in the farmer's estimate, it represents an area which has consistently received the heaviest applications of sludge. The size of the sampled plot



House
52 M
Pine Trees
(Full Length
This Side)
Butane Tanks
Soy Bean Field
2 Hectares
N
No Scale
244 M
Nelson Rd.
Dividing Line for
Soils
30 M
38 M
1
2
3
4
5
3rd Telephone
Pole
W. Peterson Rd.
4
3
R/W Post
Thornson Rd.
2
8 M
1.5 KM
1

Figure 48. Chippewa Falls, Wisconsin Treated Area

205

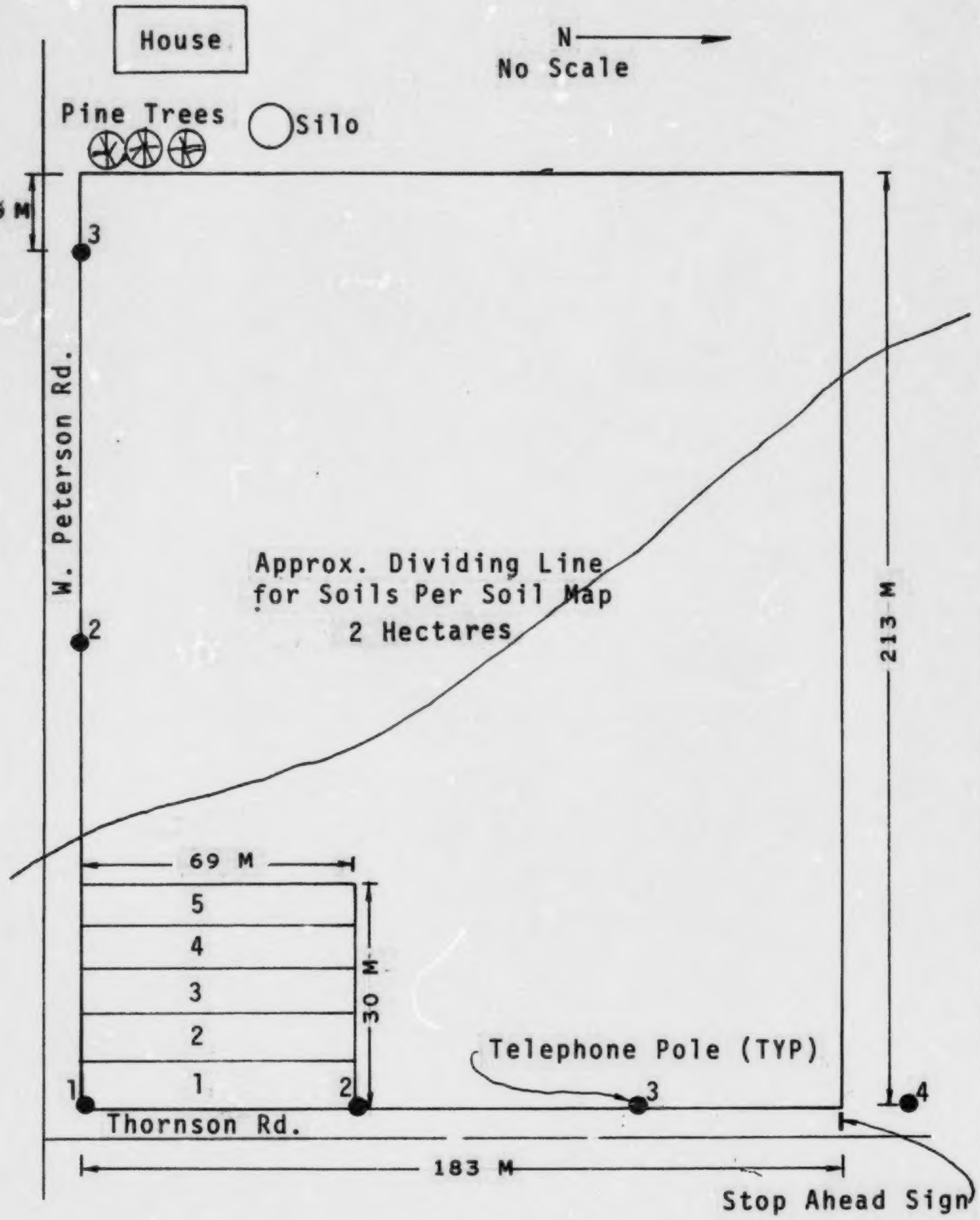

House
N
No Scale
Pine Trees
Silo
16 M
3
W. Peterson Rd.
2
Approx. Dividing Line for Soils Per Soil Map
2 Hectares
213 M
69 M
5
4
3
2
1
30 M
Telephone Pole (TYP)
1
2
3
4
Thornson Rd.
183 M
Stop Ahead Sign

Figure 49. Chippewa Falls, Wisconsin Control Area

206

was restricted to avoid sampling soils of two different series.

The control plot is located on an estimated 2 ha (4.5 acre) field, approximately 1 km (0.5 mi) south of the treated field. It measures approximately 70 x 31 m (230 x 100 ft), and also was restricted in size due to the presence of two different soil series.

Throughout the area, groundwater levels range from approximately 18 to 27 m (60 to 90 ft) below ground surface.

Farming Practices

The owner of both treated and control plots farms the treated field but rents the control field to a tenant farmer. The treated field has been consistently planted in soybeans and has a history of sludge application dating back to 1971. Sludge has been applied on a rotating basis to as many as 57 ha (140 acres) of the farmer's fields. Based on records from the STP (see Source and Description of Sludge), and assuming an even distribution of sludge to the fields, sludge application rates have been as shown in Table 62. The farmer, however, estimated that the sampled plot had received an annual average of 16 dry m tons/ha (7 dry tons/acre) assuming an average spreading of five layers of liquid sludge/year.

Soybean yields in the Chippewa Falls area have been poor for the last 5 to 6 years, averaging only approximately 10 bu/acre. The yields at the study site have been similar, with a disasterous 0.5 bu/acre in 1976. The 1976 crop was not harvested, with the exception of the five test sections. The

TABLE 62

CHIPPEWA FALLS - SLUDGE APPLICATION RATES

Year	Dry Metric Tons/ha[1]
1971	1.2
1972	3.1
1973	4.7
1974	3.9
1975	3.1

---

[1] Based on 3 percent sludge solids (STP data).

0.5 bu/acre was estimated from the yield of these sections. The farmer related that yields from other fields of similar soil types to which no sludge has been applied have been just as poor as the treated field.

As a result of the continuing poor yields, the field on which the sample plot is located and adjacent land totaling 16.2 ha (40 acres) was recently (summer 1976) sold to the city of Chippewa Falls for a future community park.

The control plot is farmed by a tenant farmer in a similar manner to that used by the owner. This field has a crop rotation history of corn, oats, clover, and soybeans; but the rotation has not been practiced since the 1974 soybean crop. The 1976 yield was 5 bu/acre.

The treated and control plots have the following in common:

- Soil preparation - Ground is plowed to a depth of 25 cm (10 in) in the springtime, disced, and harrowed. The fields are planted in soybeans in late May or early June.
- Herbicide applications - Lorox at 1.1 kg/ha (1 lb/acre) and Lasso at 2.8 l/ha (1 qt/acre) are applied.
- Lime application - 3.7 m tons/ha (3 tons/acre) are added each October.
- Fertilizer application - None have been applied to either field.

At the time of sampling, both plots had a uniform stand of soybeans ranging in height from 25 to 46 cm (10 to 18 in).

The yield difference between the treated and control plots is attributed to soil conditions. As described in Soil Description, the soil of the control plot (Burkhardt sandy loam) is more naturally fertile than the soil of the treated plot (Nymore loamy sand), and the water holding capacity of the Burkhardt is greater than the Nymore. At the time of sampling, the soil of the control plot (Burkhardt) was much less droughty than that of the treated plot (Nymore).

CLIMATE

The climate of Chippewa Falls is continental, resulting in wide and frequent variations in temperature. Storms moving eastward or northeastward into the area bring warmer weather and supply most moisture. These are usually followed by cooler air from Canada. The winters are cold and damp. The summers are generally warm with moderate humidity. Periods of hot and humid weather occur occasionally, lasting from a few days to a week at a time. The average last day for freezing temperatures in spring is April 25, and the average date for the recurrence of freezing temperature in autumn is October 16. This provides a favorable growing season for the staple crops typically planted in this area.

Approximately 60 percent of the annual precipitation falls during the months of May through September. This is the main growing season. Most of the summer rainfall comes during erratically spaced thunderstorms. Some damage from heavy rains, high winds, and hail occurs each year, but tornadoes are infrequent and cover very small areas. Snow is frequent in winter and is the predominant form of precipitation in that season. Additional meteorological data are presented in Table 63.

SOIL DESCRIPTION

Treated Plot

Nymore loamy sand is the soil type in the treated plot. It was formed on nearly level to gently sloping stream terraces and outwash plains. Due to its coarse texture, Nymore loamy sand is excessively drained. It is naturally low in fertility, organic matter content, and water holding capacity. The surface layer is easily tilled through a wide range of moisture conditions. It is subject to wind and water erosion; surface runoff is not severe, however.

Nymore loamy sand (0 to 3 percent slope), as mapped by the Soil Conservation Service, has a typical profile as delineated below:

- 0 to 20.3 cm (0 to 8 in) - very dark grayish brown loamy sand; weak fine granular structure; very friable; strongly acidic.
- 20.3 to 45.7 cm (8 to 18 in) - dark brown loamy sand; weak medium subangular structure; very friable; clay bridges sand grains; gravel 2 to 15 mm in diameter, 5 to 10 percent by volume; moderately acidic.
- 45.7 to 61.0 cm (18 to 24 in) - dark brown light loamy sand; single grained; loose, clay bridges sand grains; gravel 2 to 15 mm in diameter, 5 to 10 percent by volume; moderately acidic.

TABLE 63

CHIPPEWA FALLS, WISCONSIN

Meteorological Data For The Current Year

Station: La Crosse Standard time used: CENTRAL Latitude: 43° 52' N Longitude: 91° 15' W Elevation (ground): 651 feet Year: 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity, pct.				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Averages			Extremes						Water equivalent			Snow, Ice pellets							Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset							Temperature °F				
																																			Maximum		Minimum		
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	Hour 00 (Local time)	Hour 06 (Local time)	Hour 12 (Local time)	Hour 18 (Local time)	Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	Elev. 672 feet m.s.l.
JAN	27.2	9.0	18.1	41	10	-10	31	1446	0	1.50			18.8			79	79	70	70	24	2.2	6.4									15	5	0	4	0	22	30	7	991.2
FEB	27.9	9.5	18.7	40	21	-22	9	1292	0	1.71			20.1			77	77	66	72	30	2.4	6.9									8	5	1	3	0	18	28	9	993.2
MAR	33.5	15.5	24.5	49	20	-10	14	1248	0	2.14			18.1			83	84	70	69	25	0.5	6.1									12	6	2	2	0	15	29	4	991.9
APR	50.2	32.5	41.4	68	23	15	4	702	0	6.07			3.9			78	83	58	58	10	1.0	6.4									11	1	4	2	0	2	16	0	994.2
MAY	72.9	51.7	62.3	92	23	38	16	182	85	2.52			0.0			81	87	57	58	16	1.3	5.5									16	0	6	0	3	0	0	0	989.8
JUN	77.9	59.8	68.9	92	28	45	8	56	177	2.88			0.0			82	86	64	62	17	1.5	5.6									13	0	9	0	4	0	0	0	989.5
JUL	85.3	62.6	74.0	96	18	45	13	20	306	1.42			0.0			83	87	54	55	21	1.8	6.2									8	0	6	0	12	0	0	0	991.2
AUG	82.7	60.6	71.7	92	12	50	27	2	215	2.79			0.0			86	90	59	60	13	1.8	5.9									13	0	9	2	9	0	0	0	992.9
SEP	67.9	46.9	57.4	83	10	36	13	236	16	1.28			0.0			92	95	61	66	24	1.5	6.7									7	0	3	3	0	0	0	0	994.9
OCT	65.4	40.5	53.0	86	13	25	30	384	15	0.36			0.0			75	83	51	56	19	3.7	7.7									3	0	3	1	0	0	7	0	993.2
NOV	48.9	31.1	40.0	70	3	8	26	741	0	3.07			1.7			90	91	77	80	21	0.9	7.1									12	0	1	4	0	5	16	0	991.5
DEC	30.4	17.0	23.7	60	5	-4	18	1274	0	0.70			1.0			83	84	75	81	27	1.0	6.5									6	0	1	1	0	19	30	2	996.6
YEAR	55.9	36.4	46.2	96	JUL 18	-22	FEB 9	7563	814	26.44			63.6			82	86	64	66	21	1.1	6.4									124	17	45	22	28	81	156	22	992.5

TABLE 63 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F – Normal – Daily maximum	Temperatures °F – Normal – Daily minimum	Temperatures °F – Normal – Monthly	Temperatures °F – Extremes – Record highest	Year	Temperatures °F – Extremes – Record lowest	Year	Normal Degree days Base 65 °F – Heating	Normal Degree days Base 65 °F – Cooling	Precipitation in inches – Water equivalent – Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs. c	Year	Snow, Ice pellets – Maximum monthly	Year	Maximum in 24 hrs. c	Year
(a)				11		11					25		25		18		25		18	
J	25.0	7.1	16.1	52	1973	-32	1970	1516	0	0.96	2.86	1967	0.19	1962	1.31	1967	26.5	1971	8.7	1963
F	29.7	10.3	20.0	51	1966	-36	1971	1260	0	0.87	2.56	1959	0.03	1969	1.06	1966	31.0	1959	10.9	1959
M	40.0	22.1	31.1	80	1967	-13	1965	1051	0	2.02	3.82	1951	0.30	1958	1.64	1966	33.5	1959	13.7	1959
A	57.8	37.4	47.6	90	1970	11	1972	522	0	2.63	7.31	1973	0.60	1966	3.84	1954	17.0	1973	7.3	1952
M	69.3	48.7	59.0	94	1967	26	1971	224	38	3.70	8.83	1960	1.07	1958	2.72	1960	0.8	1960	0.8	1960
J	78.4	58.5	68.5	97	1970	40	1972	39	144	4.44	9.53	1968	1.66	1955	3.94	1967	0.0		0.0	
J	83.0	62.5	72.8	101	1974	44	1967	10	252	3.52	9.16	1953	0.16	1967	3.72	1952	0.0		0.0	
A	81.7	61.0	71.4	98	1968	40	1965	17	213	3.02	8.63	1973	0.79	1955	3.92	1962	0.0		0.0	
S	71.8	51.8	61.8	95	1971	28	1967	130	54	3.38	10.52	1965	0.42	1952	2.25	1968	T	1974	T	1965
O	61.8	41.7	51.8	86	1975	15	1972	421	12	2.05	4.47	1954	0.02	1952	2.17	1966	1.4	1959	1.2	1959
N	43.0	27.8	35.4	70	1975	7	1970	888	0	1.45	3.07	1975	0.09	1962	2.38	1958	13.0	1957	11.0	1957
D	29.6	14.0	21.8	60	1975	-22	1968	1339	0	1.04	2.55	1971	0.30	1962	0.93	1965	26.6	1968	9.1	1966
YR	55.9	36.9	46.4	101	JUL 1974	-36	FEB 1971	7417	695	29.08	10.52	SEP 1965	0.02	OCT 1952	3.94	JUN 1967	33.5	MAR 1959	13.7	MAR 1959

Month	Relative humidity pct. – Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind – Mean speed m.p.h.	Wind – Prevailing direction	Wind – Fastest mile c – Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset $	Mean number of days – Sunrise to sunset $ – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F – Max. – (b) 90° and above	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below	Average station pressure mb. Elev. 672 feet m.s.l.
(a)	11	11	11	11	25	13	18	18			17	17	17	17	25	25	25	25	11	11	11	11	3
J	76	77	67	71	8.7	S	45	32	1962		6.7	7	7	17	8	3	*	1	0	22	31	13	993.2
F	75	76	64	66	8.8	NW	37	34	1963		6.2	8	7	13	7	2	*	2	0	17	28	6	994.5
M	78	82	62	63	9.3	NW	40	34	1960		6.7	7	7	17	10	3	1	2	0	7	26	1	991.1
A	76	82	56	57	10.8	NW	53	25	1964		6.7	7	7	16	10	*	3	1	*	*	10	0	990.7
M	77	82	54	55	10.0	S	58	09	1952		6.5	7	9	15	12	0	6	1	1	0	1	0	988.2
J	85	87	59	59	8.4	S	63	34	1963		6.2	7	11	12	11	0	8	1	3	0	0	0	988.4
J	87	89	57	58	7.7	S	52	27	1961		5.6	10	11	10	10	0	7	2	8	0	0	0	991.3
A	89	93	59	61	7.5	S	63	32	1963		5.7	9	11	11	9	0	7	4	5	0	0	0	992.3
S	90	94	63	68	8.2	S	40	27	1961		5.8	9	9	12	10	0	4	4	4	0	*	0	994.1
O	80	86	61	66	9.4	S	39	34	1964		5.7	11	7	13	8	*	2	2	0	0	6	0	993.9
N	83	87	70	76	9.9	S	46	18	1958		7.1	6	6	18	8	1	1	1	0	4	21	0	992.4
D	82	84	74	78	8.7	S	43	34	1957		7.1	7	5	19	9	3	*	1	0	18	29	4	994.2
YR	81	85	62	65	8.9	S	63	32	AUG 1963		6.3	95	97	173	111	12	41	22	17	68	151	27	992.0

- 61.0 to 91.4 cm (24 to 36 in) - brown sand; single grained; loose; gravel 2 to 15 mm in diameter, 5 to 10 percent by volume; moderately acidic.
- 91.4 to 152 cm (36 to 60 in) - yellowish brown sand; single grained; gravel 2 to 20 mm in diameter, 5 to 15 percent by volume; slightly acidic.

The soil sampled for this study closely followed the above profile.

Nymore loamy sand is principally used for farming. It is suited to growing row crops, small grains, grasses, and legumes for hay and pasture with proper management. During dry periods, the soil is vulnerable to severe drought. With irrigation and other soil and water conservation practices, this problem can be relieved or overcome.

In gently sloping areas, Nymore loamy sand is subject to moderate water erosion due to surface runoff and to severe wind erosion. Minimum tillage, winter cover crops, shelter belts, grassed waterways, and contour farming help prevent soil loss. Keeping the soil under pasture also controls water and wind erosion. Proper stocking rates, pasture rotation, and timely deferment of grazing are essential in maintaining the soil fertility and good pasture.

Control Plot

The control plot is characterized by Burkhardt sandy loam. Burkhardt sandy loam was formed on broad, smooth, nearly level to gently sloping stream terraces and outwash plains. The soil is naturally low in fertility, organic matter, and water holding capacity. It is somewhat excessively drained with high permeability. The surface layer is easily tilled under a wide range of moisture conditions. The surface is subject to slow to medium runoff.

Burkhardt sandy loam (0 to 3 percent slopes), as mapped, has a typical profile as delineated below:

- 0 to 20.3 cm (0 to 8 in) - very dark brown light loam, weak, medium, subangular block structure; friable; slightly acidic.
- 20.3 to 25.4 cm (8 to 10 in) - dark brown light loam; weak, medium; platy structure; friable; less than five percent coarse fragments; moderately acidic.
- 25.4 to 40.6 cm (10 to 16 in) - dark brown light loam; moderate, medium, subangular structure; friable; thin discontinuous clay film on faces of peds; moderately acidic.
- 40.6 to 48.3 cm (16 to 19 in) - dark brown sandy loam; weak, fine, subangular blocky structure; friable, 15 percent coarse fragments; strongly acidic.
- 48.3 to 55.9 cm (19 to 22 in) - brown gravelly loamy sand; single grained; loose; greater than 20 percent gravel; moderately acidic.
- 55.9 to 112 cm (22 to 60 in) - yellowish brown and brown sand and gravel; single grained; loose; 20 to 40 percent strictified gravel; slightly acidic.

This soil has a fair potential for cropland, pasture, woodland, open land wildlife, and recreation. If the soil is used for cultivated crops, there is a severe hazard of drought, because of the low available water capacity. This can be overcome with irrigation and other water conserving practices. Gently sloping areas have a moderate erosion hazard due to surface runoff. Minimum tillage, winter cover crops, diversions and grassed waterways, and farming on the contour help prevent soil loss.

The sampled soil was observed to follow the above profile. Moisture, pH, and other analytical data for soils in the treated and control plots are presented in Table 64.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

All domestic and industrial wastewater from the town of 12,500 people is given secondary treatment at the municipal STP. In 1968, the existing facility was expanded to include secondary treatment, to accommodate heavier flows, and to meet regulatory requirements. The plant is currently serving a population equivalent of 51,000.

The STP is operated as a conventional activated sludge facility. Raw influent is passed through a mechanical bar screen, a grit removal chamber, and into primary clarifiers. The primary effluent flows by gravity to one of four aeration tanks which can be operated either in parallel or in series to permit the use of the current process, high rate activated sludge, contact stabilization, or step aeration.

After settling, aeration tank effluent flows through a contact chlorination tank before discharge to the Chippewa River. Table 65 presents treatment efficiencies covering the

TABLE 64

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

CHIPPEWA FALLS, WISCONSIN

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N(2)	PH(1)	CEC
			SAND	SILT	CLAY					MEQ/ 100GMS
	PERCENT						µ G/G			
TREATED										
SURFACE		0.74	89	7	4	0.027	10.6	1.25	5.5	10
20.46 CM		0.15	83	7	10	0.007	9.80	0.08	5.1	9
46-61 CM		0.18	89	3	8	0.013	10.5	2.03	5.1	9
61-91 CM		0.12	90	2	8	0.001	6.60	0.33	5.2	5
91-122 CM		0.06	93	0	7	0.005	6.30	1.80	5.3	4
CONTROL										
SURFACE		1.05	77	20	3	0.030	4.10	0.0	5.4	15
20-46 CM		0.49	83	12	5	0.022	3.90	0.10	5.9	11
46-61 CM		0.30	88	8	4	0.016	3.10	5.90	5.0	7
61-91 CM		0.07	93	4	3	0.012	1.00	0.02	5.1	7
91-122 XM		0.07	96	0	4	0.027	0.86	0.0	5.1	3

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 65

CHIPPEWA FALLS - SECONDARY EFFLUENT TREATMENT EFFICIENCIES

Month	Avg.Daily Flow cu m/day	Influent[1]		Effluent		% Reduction	
		BOD(mg/l)	SS(mg/l)	BOD(mg/l)	SS(mg/l)	BOD	SS
April '75	10,220	375	1588	38	121	90	92
May	9,460	219	390	53	117	76	70
June	11,730	353	858	48	99	86	88
July	9,080	523	1015	82	147	84	86
Aug.	12,490	585	2002	95	245	84	88
Sept.	11,360	394	1226	25	82	94	93
Oct.	11,730	846	2513	34	155	96	94
Nov.	12,110	633	1431	57	206	91	86
Dec.	10,220	501	832	56	103	89	88
Jan. '76	10,980	919	1432	80	108	91	92
Feb.	15,140	1124	1976	67	144	94	93
March	13,630	760	1391	20	35	97	93
April	12,110	1099	1377	31	50	97	94
May	9,080	587	698	43	46	93	93
June	14,760	1217	2397	53	86	96	96
Average	11,730	676	1408	52	116	91	90

[1] Includes supernatant from digesters.

time span April, 1975 to June, 1976. Incoming BOD and suspended solids (SS) loadings for this period show high averages of 676 and 1,408 mg/l, respectively. This strong waste is the result of a large industrial component that comprises up to 65 percent of the total flow to the plant. In addition, digester supernatant is returned to the head of the system where it is mixed with influent prior to monitoring. In periods when sludge is not removed from the digesters, this has an effect of raising the BOD and SS levels.

The treatment plant typically achieves 90 percent removal of BOD and SS. However, due to the high strength of the influent, the final discharge averages roughly 50 mg/l BOD and 115 mg/l SS. Present plans call for enforcement of stricter industrial pre-treatment regulations to reduce influent waste strength to aid the treatment facility in achieving required effluent quality of 30 mg/l of BOD and SS.

With the 1968 expansion, rated average dry weather flow is 13,200 cu m/day (3.5 mgd). Capacity for combined sewage flows during storms is 53,000 cu m/day (14 mgd). STP personnel reported that part of the sewage system remains combined with the storm drains, but that the conversion to totally separate systems is in progress. Infiltration was also reported to be a significant, but unknown, percentage of the influent.

Table 66 shows the various industrial contributors to the STP. Flow levels have been estimated. BOD levels from the brewery (STP analytical data) average approximately 1,050 mg/l.

TABLE 66

CHIPPEWA FALLS - INDUSTRIAL FLOWS

Company	Product	Estimated Average Daily Flow (cu m/day)	Comment
Packerland	Slaughtering, Rendering	2300	Primary treatment
Leinenkugel Brewing	Beer	100	High BOD-Average 1050 mg/l
Johnson Plastic Machinery	Plastic machine parts	N.A.*	Mostly cooling water
Better-Brite Plating	Chrome and other metal plating for Plastic Machinery	N.A.	--
Consolidated Thermoplastics	Plastics	N.A.	--
Amoco Chemical		3800	--

*Not available

Wastewater from Packerland receives primary treatment before discharge to the STP. Flow from industry is estimated at 65 percent. No chemicals are added throughout the treatment plant.

Sludge Stabilization and Storage

Waste activated sludge from the secondary clarifiers is returned to the primary settling tanks. Sludge from these tanks is pumped to the primary anaerobic digester having a capacity of 3,249 cu m (858,442 gal) and an equivalent detention time of roughly 150 days. Anaerobic digestion is completed in one of two secondary digesters having a combined capacity of 2,164 cu m (571,622 gal) with an equivalent detention time of about 100 days. Additional storage is provided by eight drying beds, each having 446 sq m (4,800 sq ft) of surface area and capable of holding approximately 208 cu m (55,000 gal) of liquid sludge.

Historical analytical data on sludge is shown in Table 67..

Disposal of Sewage Sludge

The city of Chippewa Falls has been disposing of liquid and dry sludge to agricultural fields for 7 years. Table 68. presents the distribution of liquid sludge to the study site covering the five-year period 1971 to 1975. Virtually all of the liquid sludge generated by the STP during this time span had been spread on this farm. Alternately, some sludge was sent to the drying beds (see Table 69). An estimated 50 percent of the dried sludge has been spread at the study site. The remaining bed-dried sludge was either trucked to neighboring farms, made available for public use, or disposed at a sanitary landfill.

TABLE 67

CHIPPEWA FALLS - STABILIZED LIQUID SLUDGE ANALYSES[1]

Parameter	Concentration ($\mu g/g$)[2]	
	A	B
Cd	2	6.5
Cu	480	431
Ni	10	32.1
Pb	--	373
Zn	400	710
Moisture (%)	--	97.0

---

[1] Data were from: A) Soil Sci. Dept. University of Wisconsin, Madison, Wisconsin, 1976, and B) Phase I stabilized sludge sample, September, 1975.

[2] Data expressed on an oven-dry weight basis.

TABLE 68

CHIPPEWA FALLS - LIQUID SLUDGE DISTRIBUTION (cu m)

Month	Year				
	1971	1972	1973	1974	1975
Jan.	0	560.9	504.5	212	286.5
Feb.	0	548.1	669.6	603.3	447
March	0	53.0	1025	412.2	330.8
April	172.6	286.9	314.9	381.5	82.9
May	177.1	137.8	338.2	720.3	180.5
June	0	422.4	683.6	783.1	742.2
July	0	451.1	421.6	794.9	746.4
Aug.	240.7	205.1	1195	1100	822.1
Sept.	413.3	457.6	1302	729.4	520.4
Oct.	526.9	277.4	1030	810.7	223.7
Nov.	395.2	149.9	826.6	314.9	924.3
Dec.	322.5	0	522.3	520.1	606.4
TOTAL (1000 gal)	2248.3	3550.2	8833.3	7382.4	5913.2

TABLE 69

CHIPPEWA FALLS - SLUDGE TO DRYING BEDS (cu m)

Month	Year				
	1971	1972	1973	1974	1975
Jan.	--	--	--	926.6	617.7
Feb.	--	--	272.5	635.9	199.8
March	490.5	635.9	--	663.1	--
April	254.3	--	--	563.2	647.2
May	363.4	--	--	--	508.7
June	--	--	--	--	--
July	327.0	--	--	--	--
Aug.	--	--	--	--	--
Sept.	363.4	--	--	--	--
Oct.	--	--	--	--	--
Nov.	--	962.9	--	--	454.2
Dec.	363.4	--	--	490.5	145.3
TOTAL	2162	1598.8	272.5	3279.3	2572.9

The STP personnel emphasized, however, that records of dry sludge to the study site were estimated and would not be reliable for use in the calculation of application rates. Therefore, application rates previously shown under Farming Practices were calculated with the assumption that no bed-dried sludge had been applied.

Liquid sludge is spread using a tank truck with a capacity of 8.7 cu m (2,300 gal). The sludge flows by gravity through a 15 cm (6 in) pipe outlet resulting in distribution estimated to cover an area approximately 300 x 2 m (1,000 x 6 ft). Dried sludge is transported via dump truck to the edge of the fields where it is stockpiled and later transferred to a manure spreader for distribution on the fields.

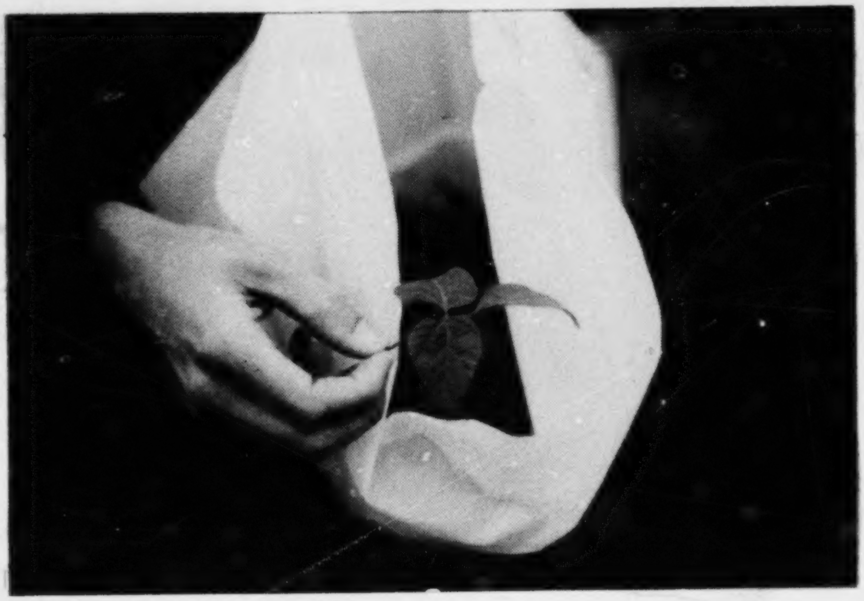
Interviews with STP personnel and the farmer indicate no apparent aesthetic or environmental problems associated with the sludge spreading operation. No odor problems were reported with use of the liquid sludge, but were evident when dry sludge was left in large piles for several days at the edges of fields.

Photographs 20 through 23 show, respectively, the treated field, the sampled trifoliate, field-dried sludge, and the tank truck.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

The Chippewa County Public Health Department, the Wisconsin State Department of Natural Resources, and the local newspaper were contacted to assess public attitudes and awareness of sludge spreading practices. The first two agencies were aware of the

Photograph 20
Treated Field



Photograph 21 21
Trifoliate

Photograph 22
Bed Dried Sludge

Photograph 23
Tank Truck

practice and could not recall any public opposition to sludge spreading.

An interview with the Outdoor Editor of the Herald Telegram indicated that several articles relative to sludge spreading had been published, but he was not able to locate copies of the texts. He related the following:

- In the early 1970's, several articles relevant to sludge spreading were printed. These were very general in nature and were obtained from Copley News Service.
- Several years ago (exact time unknown), an article describing the purchase of sludge spreading vehicles was printed. This was general in nature and only described the trucks
- From time to time, the Herald Telegram has covered events at the local town meeting. The editor recalls that one of these articles made note of sludge as a fertilizer source.

No articles adverse to sludge spreading have ever appeared in the local newspaper.

Interviews with local Soil Conservation Service personnel indicated their awareness and acceptance of sludge spreading practices. It was also their opinion that there was little public awareness of sludge utilization practices.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

The Wisconsin Department of Natural Resources in 1975 issued Technical Bulletin No. 88, entitled Guidelines for the Application

Retype at least [illegible] to the end "land"
at end of line

of Wastewater Sludge to Agricultural Land in Wisconsin. The preface to this publication reads as follows:

> "This publication gives guidelines for applying processed (i.e., not raw) sewage sludge to agricultural and forest lands. It has been prepared to assist Wisconsin Department of Natural Resources personnel in the granting of discharge permits (Chapter 147, 1973 Assembly Bill 128). Section 147.02, Water Pollutant Discharge Elimination; Permits, Terms and Conditions, states that "the disposal of sludge from a treatment work by any person shall be unlawful unless such disposal is done under a permit issued by the department." Section 147.26, Design of Publicly Owned Treatment Facilities, states that "the department shall encourage the design of publicly owned treatment works which provide for: (a) The recycling of sewage pollutants by using them in agriculture, silviculture or aquaculture; (b) The ultimate disposal of sludge in a manner not resulting in environmental hazards.
>
> "Sludge application on land must be considered as an alternative disposal method. This guideline can be used for screening the land application alternative, evaluating environmental effects, assessing of other important non-monetary effects, and for developing a land

> application program in consultation with qualified specialists if this alternative is selected. The guideline addresses the properties of sludge and alternative handling methods, factors that determine environmentally-acceptable loading rates, current application technology and site selection, management and monitoring. It does not consider specifics of all possible site properties, handling options and management variables. It was prepared by the University of Wisconsin Soil Science Department and the Wisconsin Department of Natural Resources.
>
> "These guidelines are based on current knowledge and should be revised as new information becomes available. Factors affecting the limitations to sludge application rates from heavy metals are not well understood, and new technology for sludge application should become available in the near future."

The "guidelines" have not yet been implemented into a comprehensive administrative policy by the Department of Natural Resources. The Health Officer of Chippewa Falls reviewed a city regulation prohibiting the surface disposal of sludge within the city limits of Chippewa Falls. This ordinance does not affect the case study site since the farm is located outside the city limits.

The sewage treatment plant has a mandatory innoculation program for all employees which provides protection against typhoid, tetanus, and polio.

ECONOMICS

The Chippewa Falls STP has maintained a detailed account of capital purchases since the beginning of the sludge spreading program (see Table 70). In addition to these prices of equipment shown, several surplus military vehicles and a 5.1 cu m (1,350 gal) tank were obtained at no cost. This smaller tank was used for spreading prior to purchase of the 5-ton truck and 8.7 cu m (2,300 gal) tank. The Marlow piston pump was purchased to be used exclusively for pumping sludge from the digester to the tank truck.

Records of daily expenditures have not been separately maintained from general plant expenses. The STP superintendent, therefore, was asked to estimate labor and operation and maintenance (O&M) costs. These costs, and a cost analysis of the sludge spreading operation, are presented in Table 71. The O&M costs include a $2,000 engine overhaul to the 5-ton Jeep truck. The other factor which accounts for the high O&M cost is the distance to the study site, approximately 8 km (5 mi).

The cost analysis includes both the liquid and bed-dried sludge. From Tables 68 and 69 it can be seen that of the total 8,486 cu m (2.2 mg) of liquid sludge generated, approximately 30 percent, or 2,573 cu m (.7 mg) went to the drying beds.

SAMPLING AND ANALYSIS

Sludge

On August 3 and November 16, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifier and the secondary digester.

TABLE 70

CHIPPEWA FALLS - CAPITAL EXPENDITURES

Description	Year Purchased	Cost ($)
1968 Chevy Dump Truck - 1 Ton	1970	2,880
1967 Jeep Military 5-Ton Truck	1974	1,250
2,300 gal (8.7 cu m) Tank for Jeep Truck	1974	2,000
2 - Sludge Piping Facilities	1969	400
Marlow Piston Pump	1975	10,000

TABLE 71

COST FOR DISPOSAL OF LIQUID SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation[1]			
5T Army Truck cost: $2,000			$ 339
1968 Chevy Dump Truck cost: $2,880			475
Stationary Equipment Depreciation[2]			
1969 Piping Facilities: $400			58
1975 Marlow Pump: $10,000			1,456
1974 300-gal Tank (8.7 cu m) cost: $2,000			291
Total Annual Capital Cost			$ 2,619
Annual Operating Cost			
Personnel	Hourly Rate	% Time Worked	
1 Operator	$5.00	32.4	$ 3,365
Fringe Benefits (25 percent)			841
Vehicle Maintenance and Operation			11,436
Total Annual Operating Cost			$15,642
Total Annual Capital and Operating Cost			18,261
10 Percent Contingency Factor[3]			1,826
Total Annual Cost			$20,087

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$20,087}{280 \text{ dry tons}} = \frac{\$79.08/\text{dry m ton}}{(\$71.74/\text{dry ton})}$$

---

[1] Vehicles were fully depreciated over 8 years assuming 8 percent interest, equivalent to $169.68 per $1,000 annually.

[2] Equipment was fully depreciated over 10 years at 8 percent interest, equivalent to $145.56 per $1,000 annually.

[3] A 10 percent contingency factor is added on administrative overhead.

Soil

On August 3 and 4, 1976, surface and subsurface samples were obtained from both the treated and control plots. As shown in Figure 48 and 49 both the treated and control plots were divided into five sections. Approximately 30 individual core samples from the surface 0 to 20 cm (0 to 8 in) were obtained per section with a 2.5 cm (1 in) diameter stainless steel split tube sampler.

Subsurface soil samples were obtained from the treated and control plots with an 8 cm (3 in) diameter stainless steel bucket auger. The surface top 20 cm (8 in) was discarded from the auger. Samples were then taken between 20 and 46 cm (8 to 18 in) and labeled Horizon A; 46 and 61 cm (18 to 24 in) Horizon B; 61 and 91 cm (24 and 36 in) Horizon C; and 91 and 122 cm (36 and 48 in) Horizon D.

Plants

On August 3 and 4, 1976, plant tissue samples were obtained from both the treated and control plots. Only the top mature trifoliate was sampled. Approximately 100 such trifoliates were picked from separate plants from each section resulting in an estimated 1 kg (2 lb) sample per section.

On October 4, 1976, mature soybeans from both the treated and control plots were sampled by running a combine through the respective sections and accumulating the beans into premarked sample bags. Each of the 10 sections sampled resulted in approximately 2 kg (4 lb) of soybeans. The beans were screened through a U.S. No. 4 screen to eliminate small particles of chaff and

234

dirt. The +4 fraction was hand-picked clean of rocks, stems and other non-related debris prior to compositing and analyses.

Tables 72 through 79 present the following:

Table	
72	Chemical Characterization of Stabilized Sludges
73	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
74	Total Metal Concentrations in Individual Subsurface Soil Samples
75	Metal Concentrations in Surface Soils and Plants
76	Metal Concentrations in Soy Bean Samples
77	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
78	Parasites in Sludges, Soils, and Plants
79	Concentrations of Microbes in Sludges, Soils, and Plants

Figures 50 to 59 present particle size analyses of the various soil composites by depth.

TABLE 72

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM CHIPPEWA FALLS, WISCONSIN

	8/3/76	11/6/76	Average
Volatile Solids (%)	57.1	55.7	56.4
NO_3 - N	1.9	24.1	13.0
NH_4 - N	19070	23233	21152
Organic N	22548	26606	24577
P	11903	14828	13366
K	2419	2018	2218
Na	4903	8458	6681
Ca	14161	13651	13906
Mg	4967	5514	5241
SO_4	n.d.	<133	<66
Cl	8613	13169	10891
Ag	9.68	2.14	5.92
As	1.29	3.75	2.52
B	45.8	39.1	42.5
Cd	7.10	6.96	7.03
Cr	1039	1494	1267
Co	6.45	5.89	6.17
Cu	1168	1568	1368
Fe	11903	14722	13313
Hg	4.77	43.4	24.1
Mn	197	236	217
Mo	5.16	8.03	6.60
Ni	20.6	21.4	21
Pb	152	53.8	103
Se	6.13	9.10	7.6
Zn	1058	1322	1190
H_2O (%)	96.9	98.1	97.5
pH	7.8	7.6	

All units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 73

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

CHIPPEWA FALLS, WISCONSIN

PLOT/ DEPTH:	TOTAL METALS (2)					DTPA EXTRACTABLES			
	CD	CU	NI	ZN	PB	CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	0.42	17.4	14.2	49.3	9.90	0.06	3.44	1.00	4.28
20-46 CM.	0.38	10.5	16.7	29.4	4.40	0.03	0.55	0.36	0.61
46-61 CM.	0.35	11.3	16.1	21.8	4.00	0.02	0.57	0.39	1.00
61-91 CM.	0.31	13.0	14.6	22.1	2.40	0.02	0.34	0.41	0.89
91-122 CM.	0.44	18.5	14.4	24.7	2.70	0.03	0.31	0.68	1.17
CONTROL									
SURFACE	0.46	7.60	15.2	31.3	8.50	0.06	0.42	0.33	1.54
20-46 CM.	0.34	7.60	14.3	24.2	5.70	0.03	0.23	0.33	0.39
46-61 CM.	0.48	12.2	18.3	30.2	5.60	0.02	0.17	0.41	0.79
61-91 CM.	0.31	15.7	19.6	27.8	4.00	0.03	0.36	0.33	1.12
91-122 CM.	0.33	13.8	16.3	19.5	2.10	0.02	0.23	0.21	0.89

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 74

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES (1)

CHIPPEWA FALLS, WISCONSIN

SECTION/ DEPTH	TREATED CD	TREATED CU	TREATED NI	TREATED ZN	CONTROL CD	CONTROL CU	CONTROL NI	CONTROL ZN
	µG/G				µG/G			
SECTION 1								
20-46 CM.	0.43	10.4	15.7	31.8	0.40	9.19	15.2	29.2
46-61 CM.	0.27	13.4	16.7	27.2	0.35	11.8	17.0	20.6
61-91 CM.	0.26	14.4	13.4	19.8	0.30	13.7	17.6	20.6
91-122 CM.	0.29	15.5	16.4	19.6	0.36	13.6	14.1	18.3
SECTION 2								
20-46 CM.	0.37	10.1	15.5	31.7	0.47	7.62	15.4	25.9
46-61 CM.	0.38	11.9	18.2	27.0	0.32	9.25	15.3	21.2
61-91 CM.	0.30	11.9	13.6	19.6	0.65	16.7	24.6	27.6
91-122 CM.	0.49	15.5	17.9	20.8	0.40	14.0	16.8	21.6
SECTION 3								
20-46 CM.	0.44	11.3	17.9	30.3	0.31	7.10	14.2	28.8
46-61 CM.	0.36	14.6	13.1	19.9	0.29	8.55	15.2	22.1
62-92 CM.	0.29	12.0	13.6	17.3	0.35	13.9	20.5	25.7
91-122 CM.	0.32	12.5	13.7	15.5	0.35	13.2	13.8	17.8
SECTION 4								
20-46 CM.	0.32	9.91	5.72	8.7	0.34	8.07	16.1	23.7
46-61 CM.	0.35	12.2	16.4	21.9	0.39	10.3	15.9	20.7
61-91 CM.	0.38	12.2	15.6	27.2	0.35	16.8	16.4	23.9
91-122 CM.	0.25	11.5	13.5	14.5	0.36	12.7	17.9	34.6
SECTION 5								
20-46 CM.	0.38	9.03	14.9	26.9	0.43	8.61	5.52	8.9
46-61 CM.	0.26	13.2	11.6	20.7	0.39	16.7	20.3	24.7
61-91 CM.	0.41	20.6	15.6	18.3	0.31	13.1	15.0	20.1
91-122 CM.	0.34	13.0	25.8	17.0	0.40	14.5	15.4	20.8

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 75

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS[1]

CHIPPEWA FALLS, WISCONSIN

SAMPLE	SURFACE SOIL CD	CU	NI	ZN	PB[2]	PLANT CD	CU	NI	ZN	PB[2]	ORG-N[2]
	μG/G					μG/G					
TREATED											
COMPOSITE	0.42	17.4	14.2	49.3	9.90	0.97	11.9	10.8	87.5	5.50	1.31
SECTION 1	0.42	21.6	14.2	50.5		2.31	14.9	14.5	149		
SECTION 2	0.47	19.7	13.5	47.9		0.95	15.1	10.4	113		
SECTION 3	0.48	17.8	14.9	46.7		0.92	12.5	10.7	60.5		
SECTION 4	0.49	16.0	15.4	48.9		1.48	11.5	17.8	111		
SECTION 5	0.35	15.0	15.1	45.8		1.24	12.6	13.3	89.9		
MEAN	0.44	18.0	14.6	48.0		1.38	13.3	13.3	109		
STD. DEV.	0.06	2.69	0.77	1.84		0.57	1.59	3.04	26.44		
CONTROL											
COMPOSITE	0.46	7.60	15.2	31.3	8.50	0.82	10.4	10.4	60.4	8.20	2.36
SECTION 1	0.44	7.80	14.5	32.0		1.21	11.1	15.5	65.2		
SECTION 2	0.42	7.30	14.6	31.0		0.66	10.0	8.70	51.6		
SECTION 3	0.41	7.20	14.0	32.0		0.72	11.0	9.10	56.4		
SECTION 4	0.38	7.10	13.1	29.4		0.80	9.6	9.60	52.5		
SECTION 5	0.53	7.70	14.6	32.6		0.77	10.6	9.90	60.8		
MEAN	0.44	7.42	14.2	31.4		0.83	10.5	10.6	57.3		
STD. DEV.	0.06	0.31	0.64	1.26		0.22	0.65	2.80	5.72		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.

TABLE 76

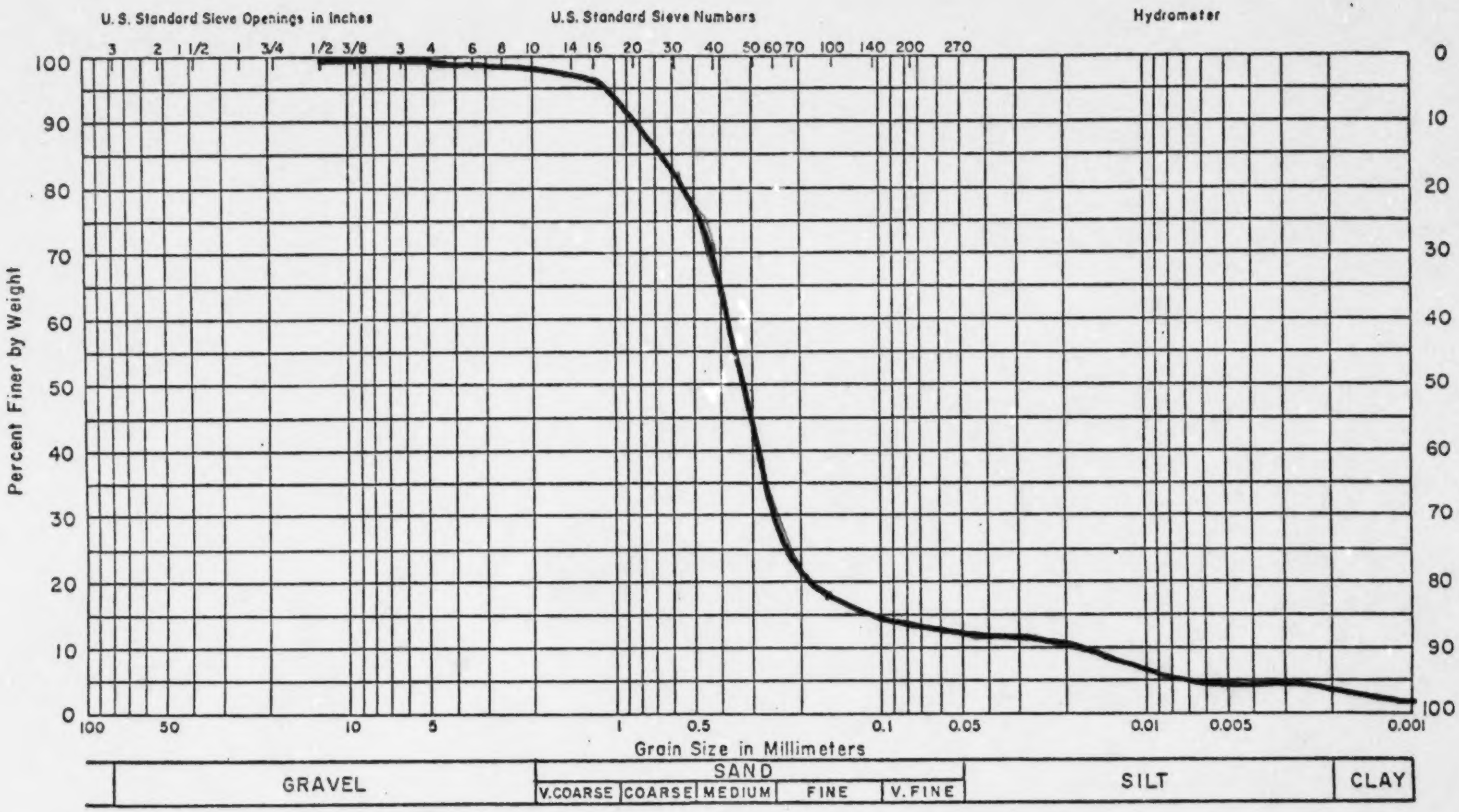
METAL CONCENTRATIONS IN SOY BEAN SAMPLES[1]

CHIPPEWA FALLS, WISCONSIN

SAMPLE	SURFACE SOIL CD	 CU	 NI	 ZN	 PB	PLANT CD	 CU	 NI	 ZN	 PB[2]	 ORG-N[2]
	µG/G					µG/G					
TREATED											
COMPOSITE						0.12	18.0	4.01	93.1	0.74	5.21
SECTION 1						0.12	18.3	3.09	86.2		
SECTION 2						0.09	19.9	5.18	106.0		
SECTION 3						0.15	19.8	4.41	99.8		
SECTION 4						0.19	18.9	3.57	92.6		
SECTION 5						0.11	19.0	4.06	99.5		
MEAN						0.13	19.2	4.06	96.8		
STD. DEV.						0.04	0.67	0.80	7.6		
CONTROL											
COMPOSITE						0.07	11.4	1.18	74.3	0.60	5.23
SECTION 1						0.03	11.7	1.20	71.3		
SECTION 2						0.06	10.8	2.25	72.6		
SECTION 3						0.06	11.5	1.03	69.2		
SECTION 4						0.12	10.7	1.88	67.6		
SECTION 5						0.09	11.0	2.74	67.1		
MEAN						0.07	11.1	1.82	69.6		
STD. DEV.						0.03	0.44	0.71	2.36		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) ANALYSIS ON COMPOSITE ONLY.

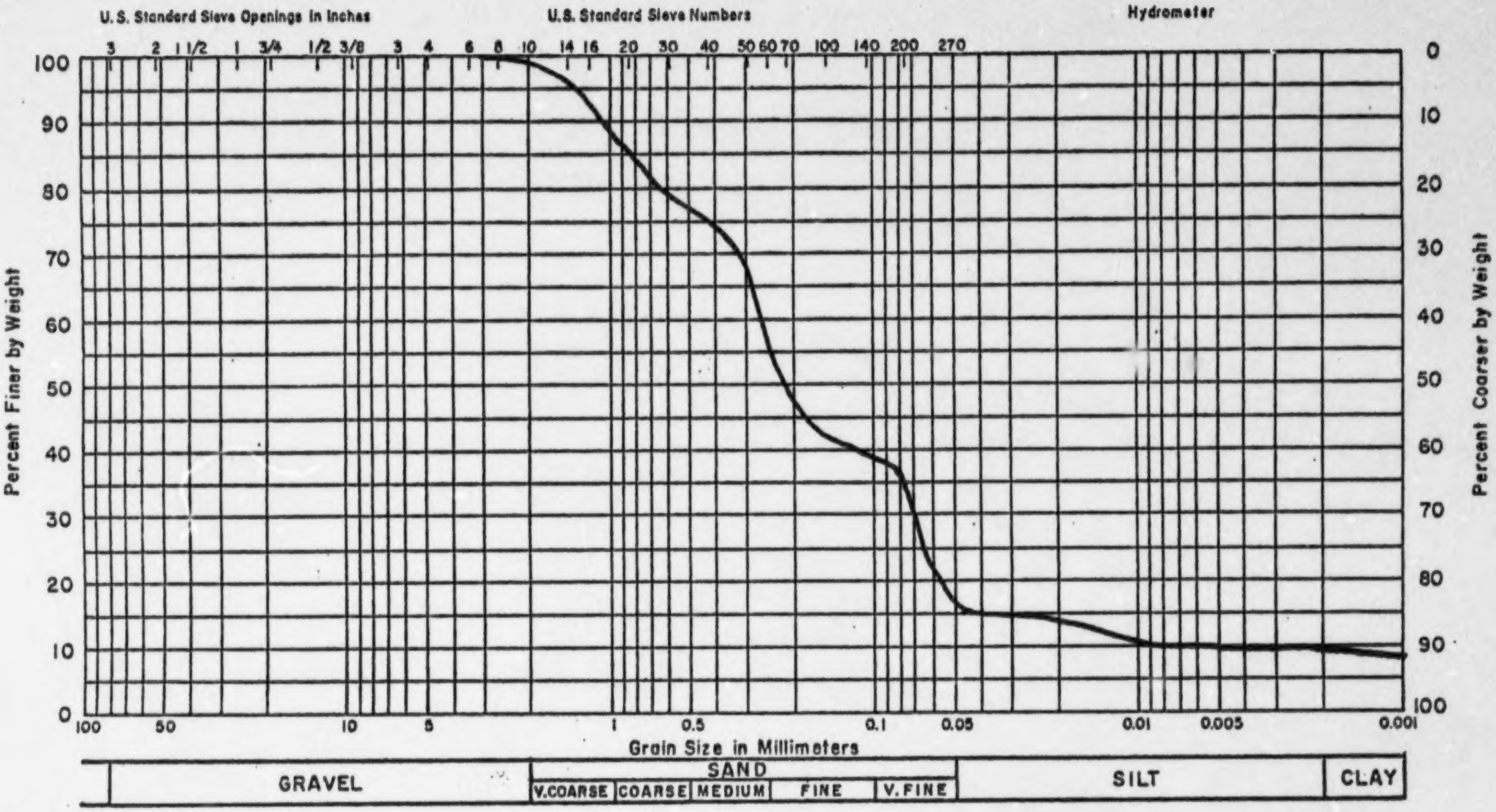


SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1251	Chippewa Falls	89	7	4	Sand
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 50 Chippawa Falls, Wis., Particle Size Analysis

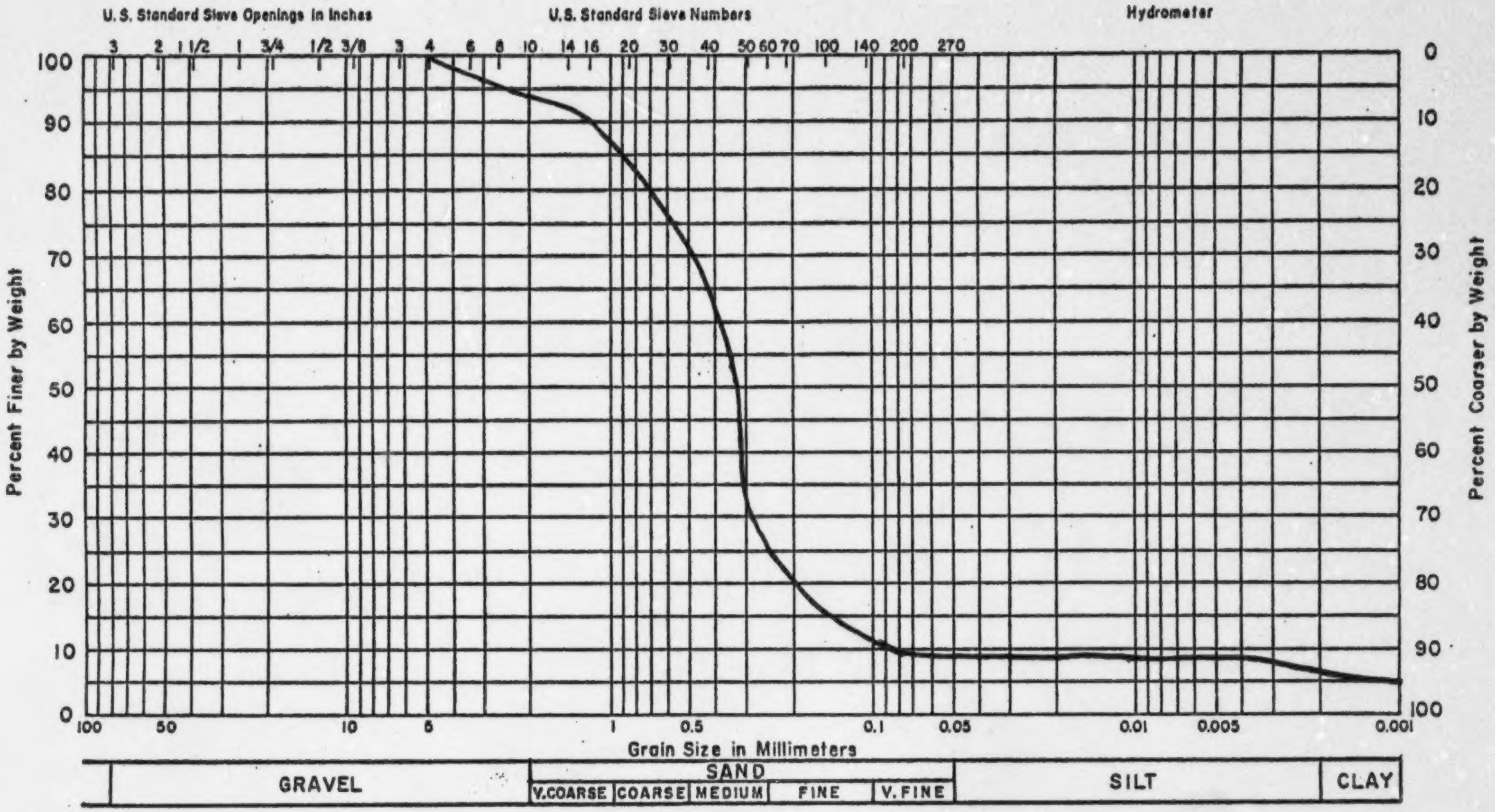
(241)



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1257	Chippewa	83	7	10	Loamy Sand/Sand
	Falls				
	Treated				
	20-46 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

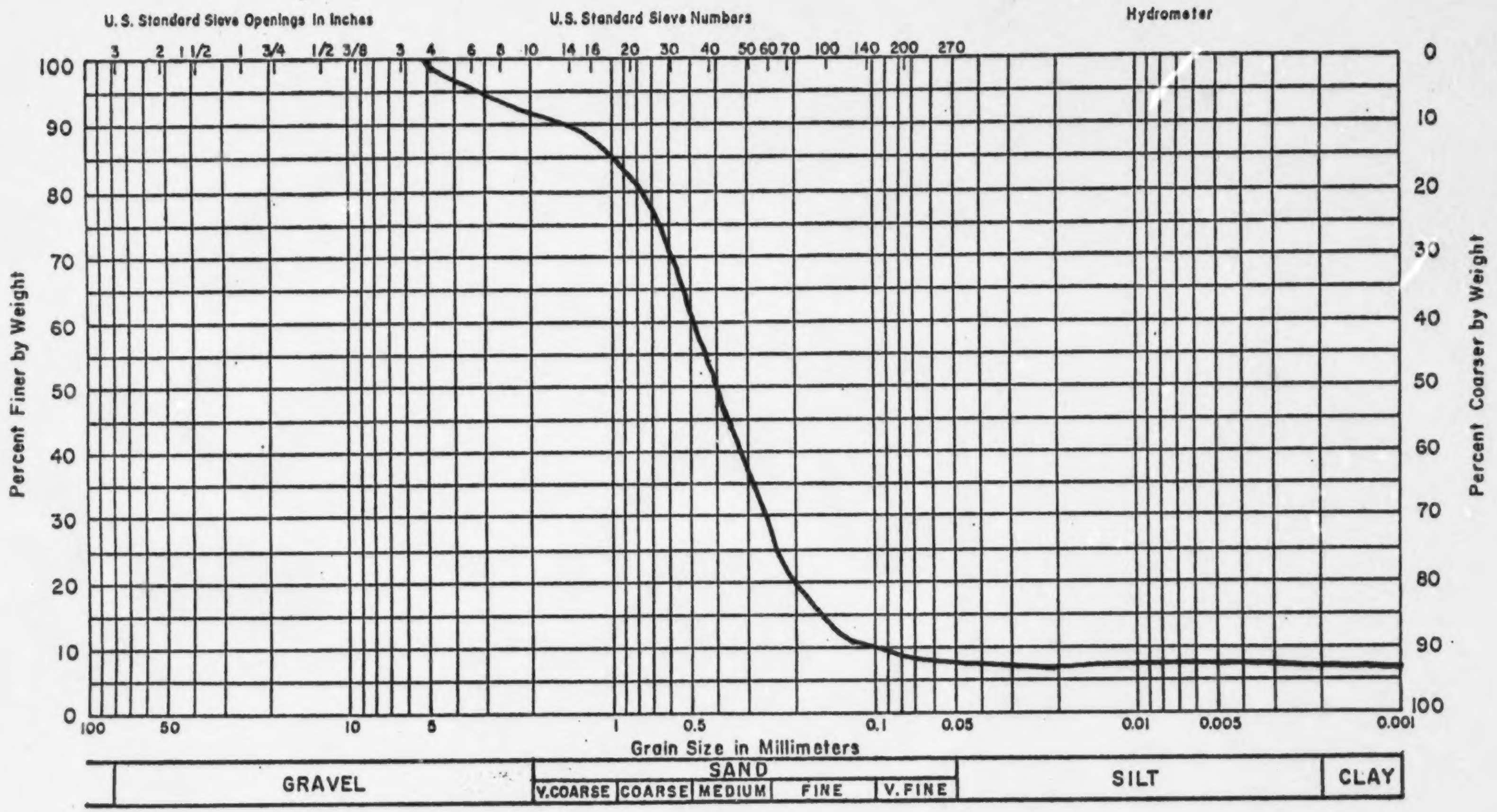
Figure 51 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1263	Chippewa Falls Treated 46-61 cm	89	3	8	Loamy Sand/Sand

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

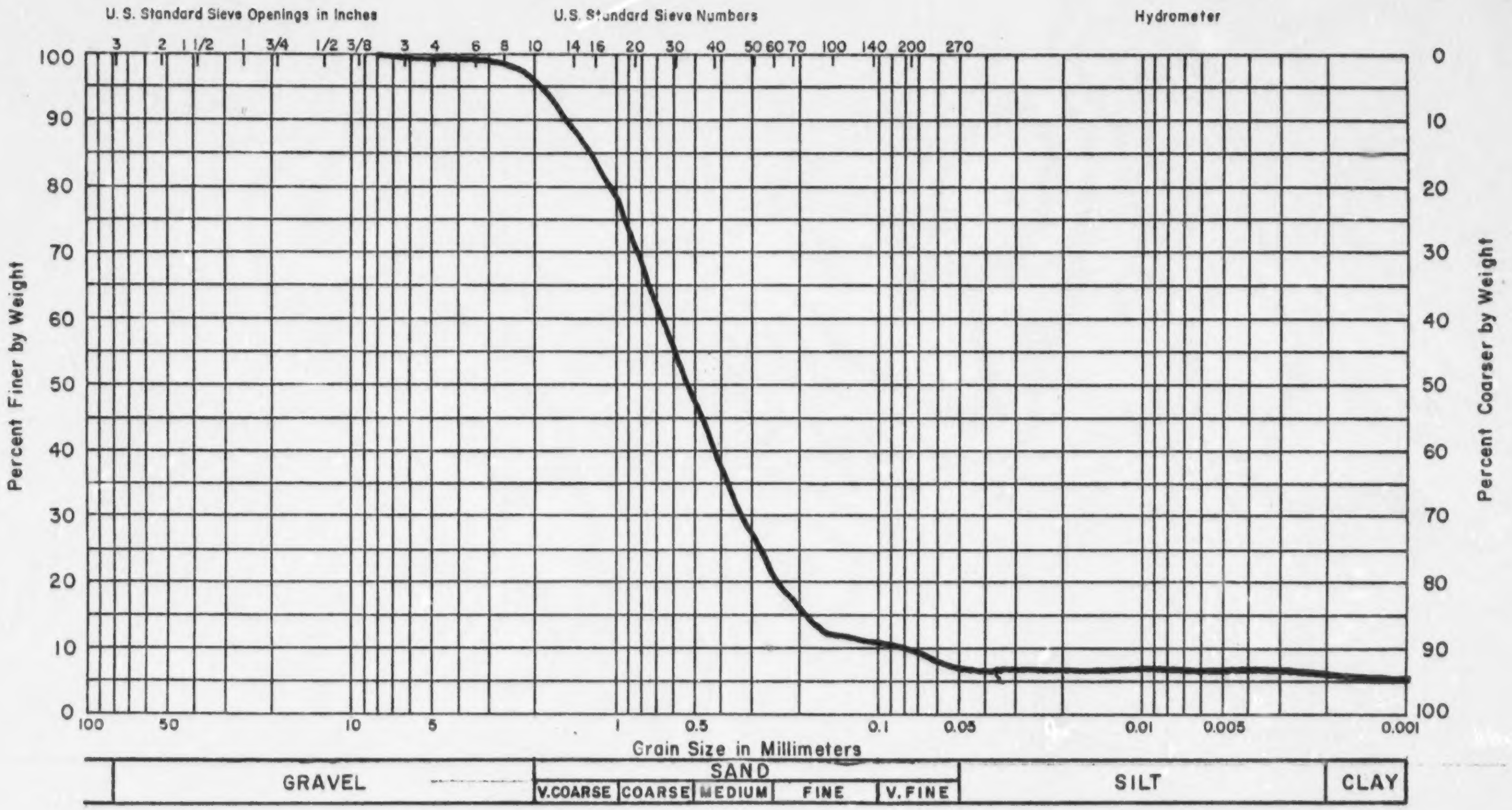
Figure 52 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1269	Chippewa Falls	90	2	8	Loamy Sand/Sand
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

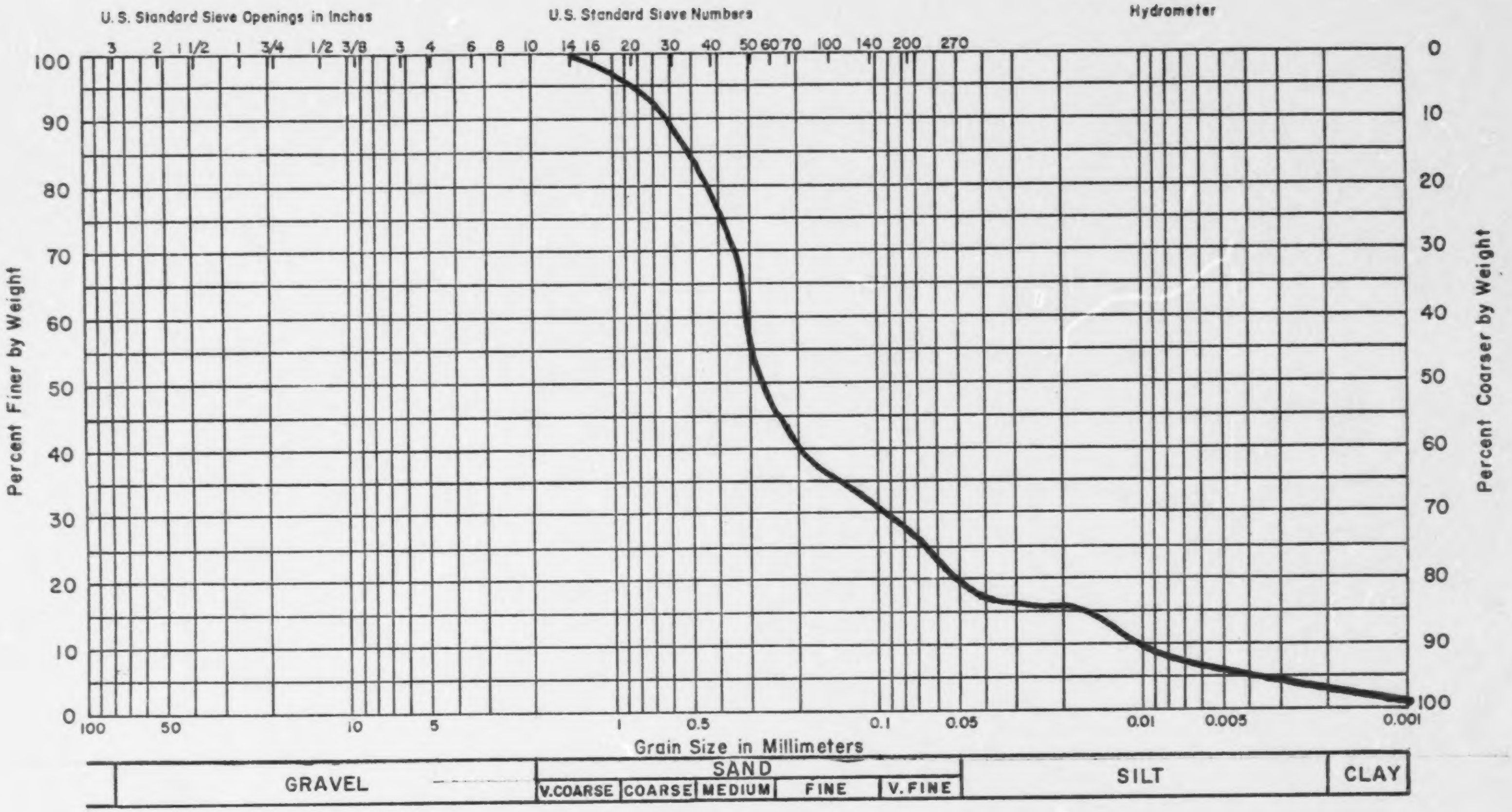
Figure 53 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1275	Chippewa Falls	93	0	7	Sand
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

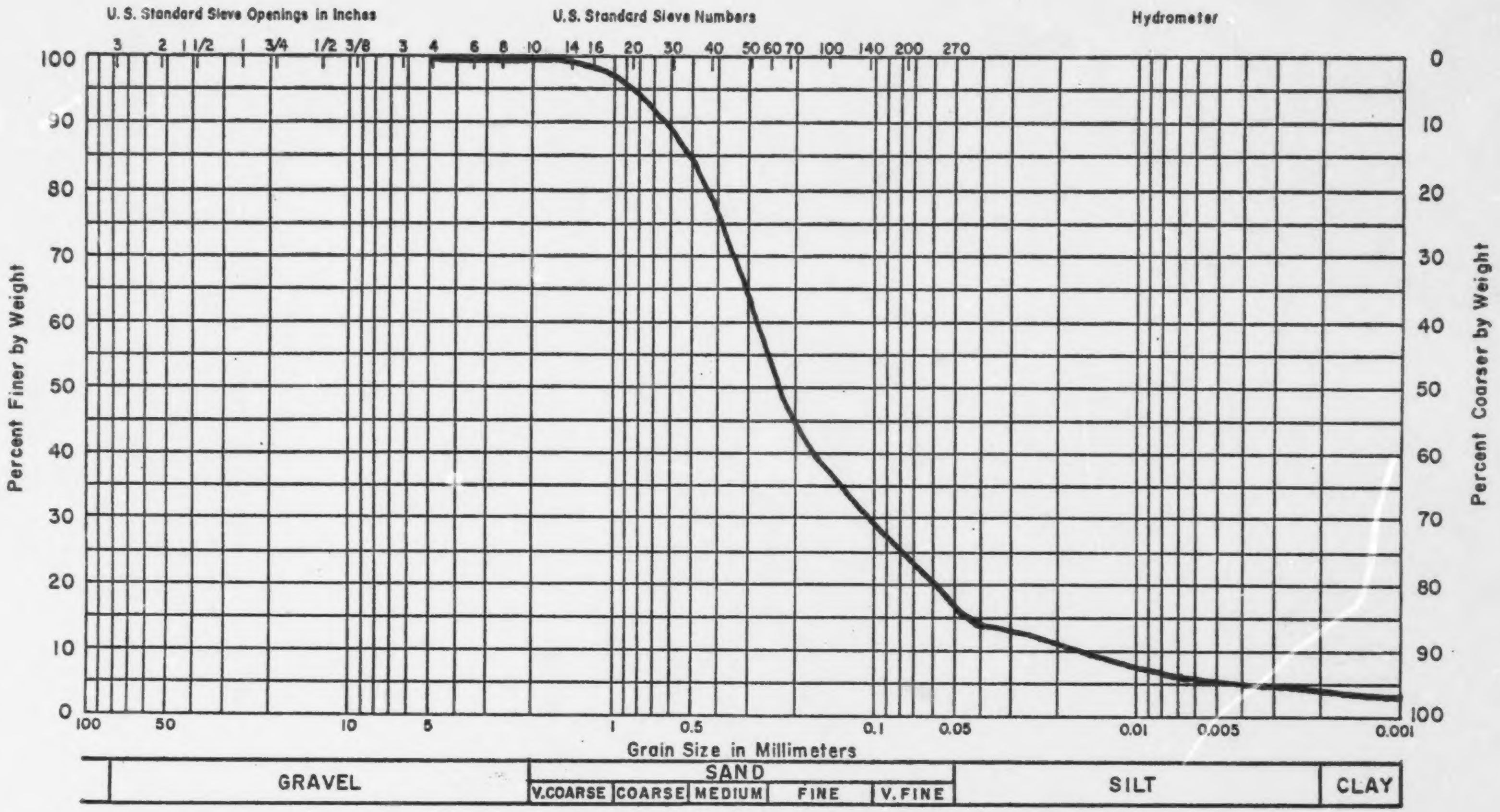
Figure 54 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1221	Chippewa Falls Control Surface	77	20	3	Loamy Sand

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

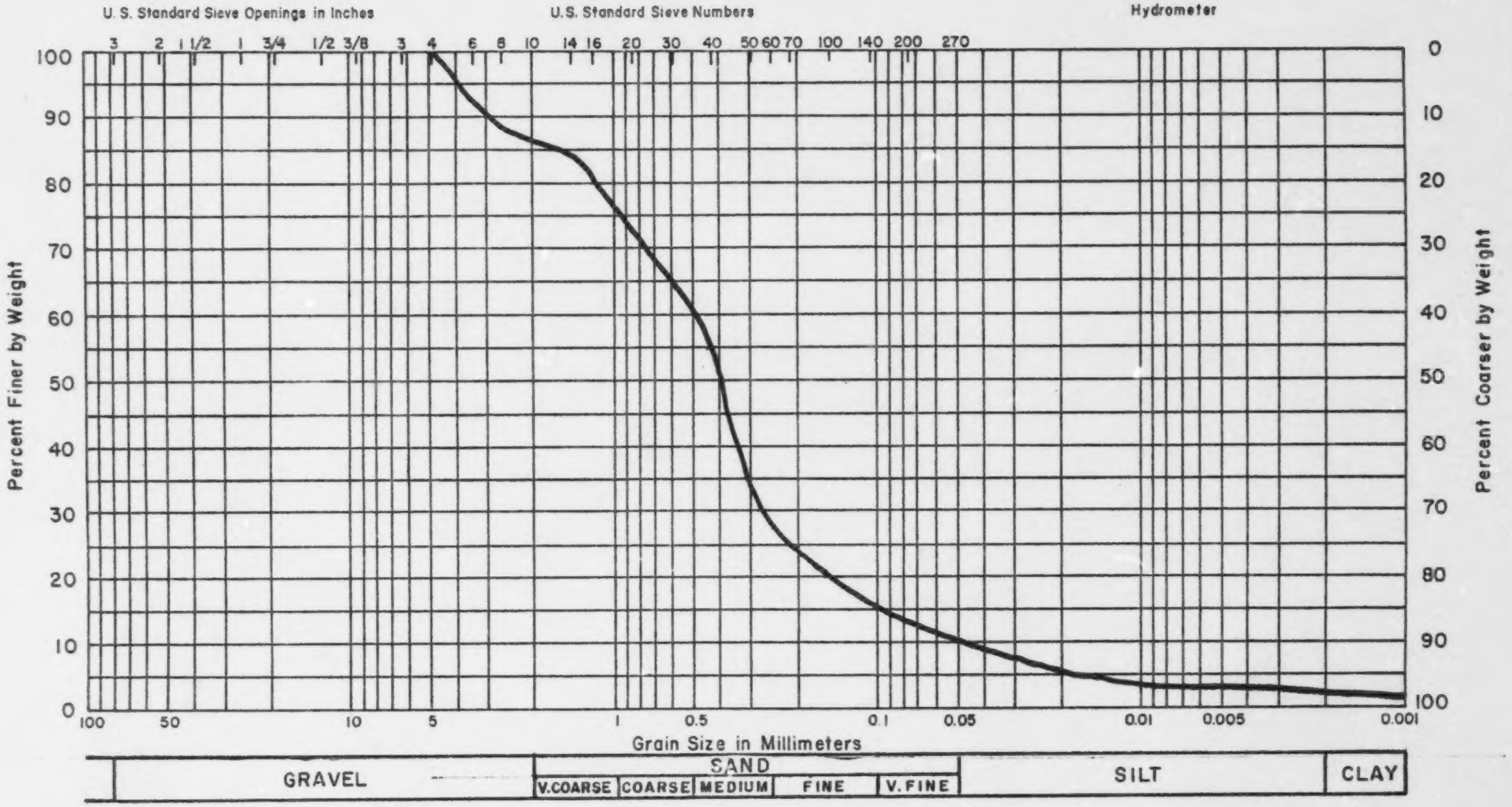
Figure 55 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1227	Chippewa Falls	83	12	5	Loamy Sand
	Control				
	20-46 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 56 Chippawa Falls, Wis., Particle Size Analysis

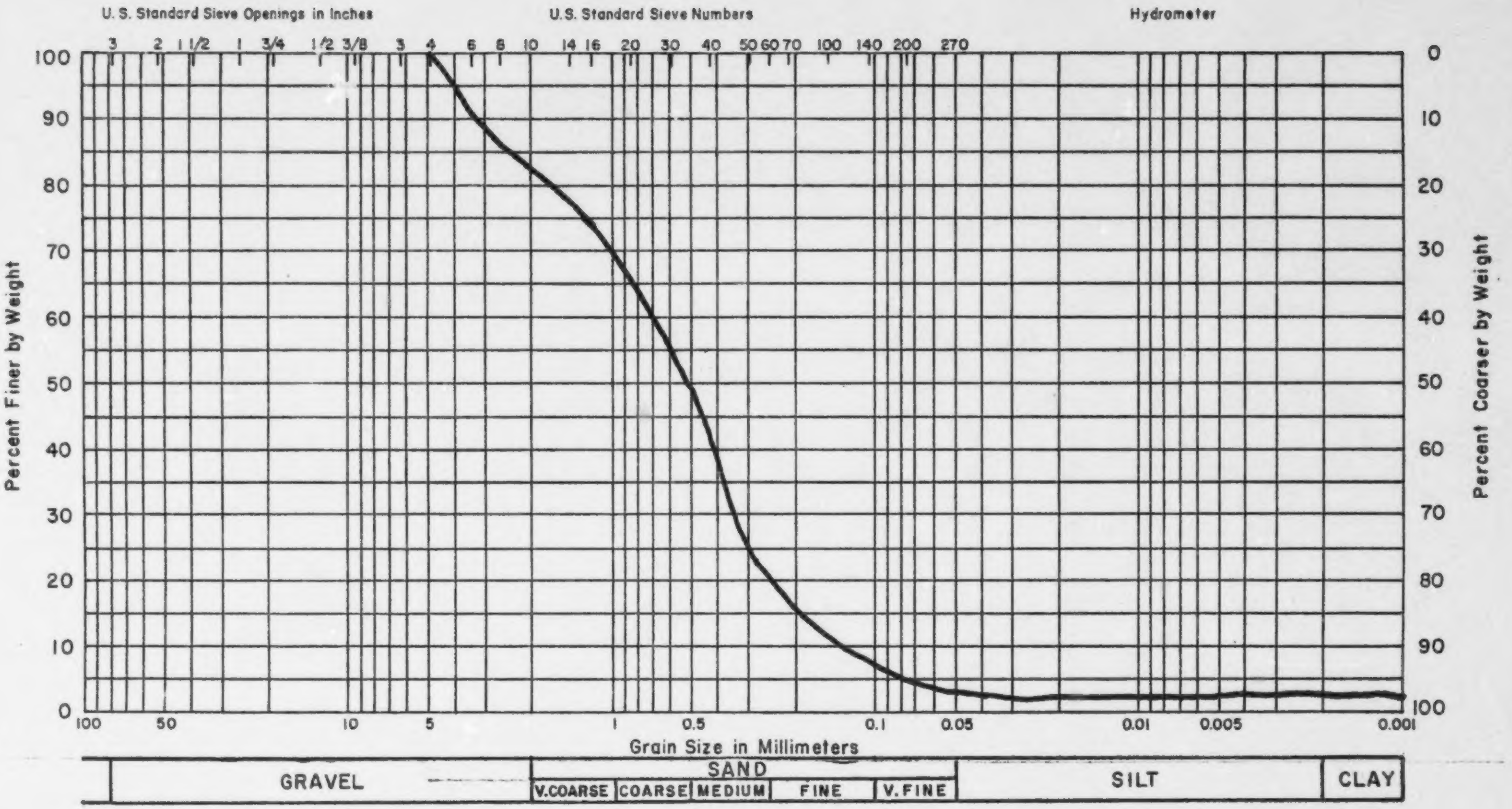


SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1233	Chippewa Falls	88	8	4	Sand
	Control				
	46-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 57 Chippawa Falls, Wis., Particle Size Analysis

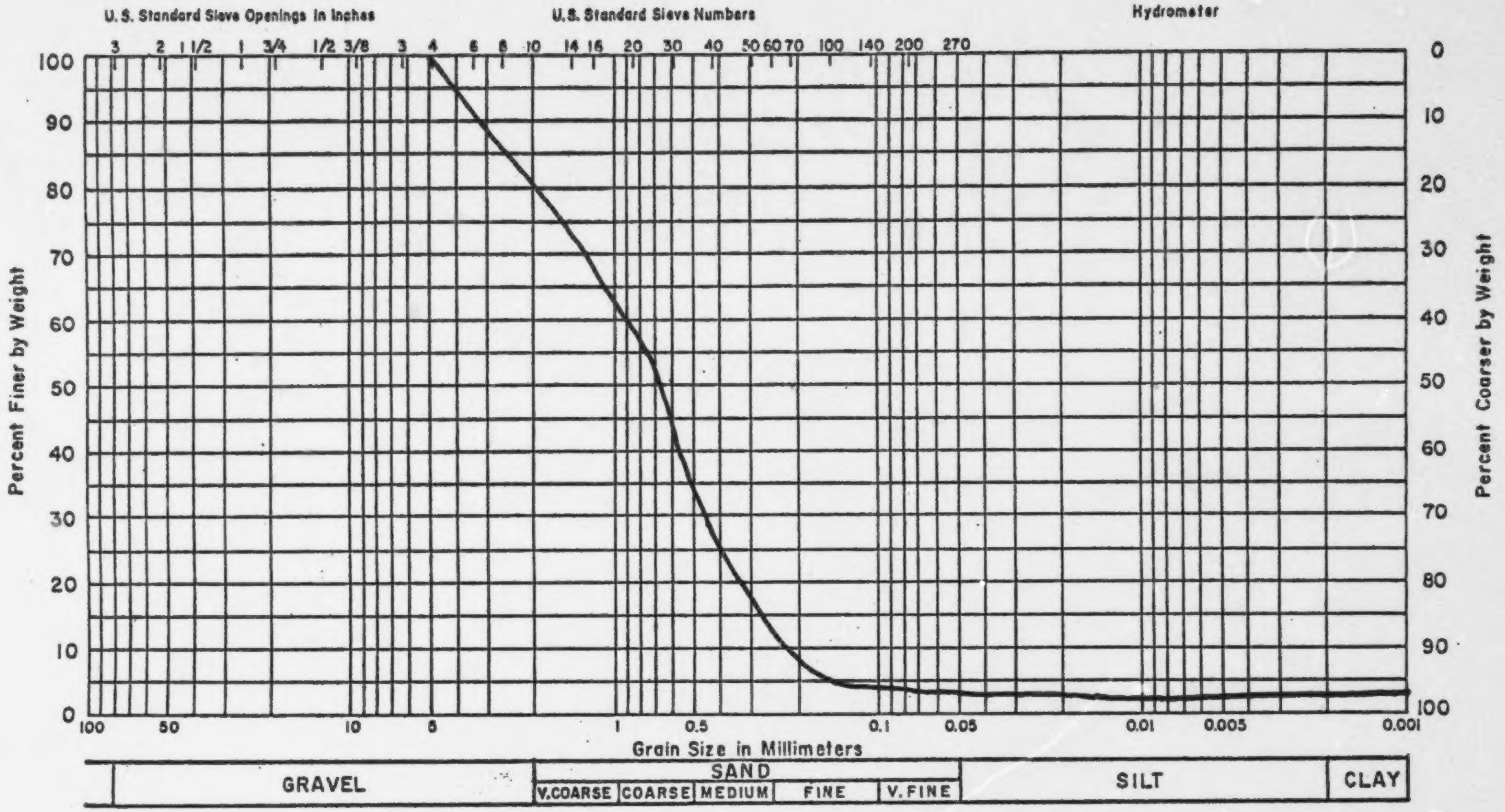
V-610



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1239	Chippewa	93	4	3	Sand
	Falls				
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 58 Chippawa Falls, Wis., Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1245	Chippewa Falls	96	0	4	Sand
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 59 Chippawa Falls, Wis., Particle Size Analysis

TABLE 77

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

CHIPPEWA FALLS, WISCONSIN

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	μg/kg		
Soil			
Surface Composites	<0.001[1]	<0.001	DDT
	<0.001	<0.001	DIELDRIN
	10.5	<0.06	PCB 1221
	<0.001	<0.06	PCB 1248
Plant			
Composites	<0.01	<0.01	DDT
	<0.01	<0.01	DIELDRIN
	<0.75	<0.75	PCB 1221
	<0.5	<0.5	PCB 1248
Composites	<0.001	<0.001	DDT
	<0.003	<0.003	DIELDRIN
	0.4	<0.06	PCB 1221
	0.4	<0.06	PCB 1248
	(8/3/76)	(11/6/76)	
Stabilized Sludge	<0.06	<0.05	DDT
	<0.03	0.4	DIELDRIN
	<0.01	<0.01	PCB 1221
	<1.9	335	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 78

PARASITES IN SLUDGES, SOILS, AND PLANTS

CHIPPEWA FALLS, WISCONSIN

Sample Description	Results
Sludge	
Raw (8/3/76)	Negative
Raw (11/16/76)	Negative
Stabilized (8/3/76)	Negative
Stabilized (11/16/76)	Negative
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
20-46 cm	Negative
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
20-46 cm	Negative
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 79

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS,[1] - 1976
CHIPPEWA FALLS, WISCONSIN

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 8/3	3.75×10^9	ND	+	-	-	ND	+	-	-	1.2×10^6	+	+	+	1.2×10^9	+	+	+
Raw 11/16	3.50×10^{10}	ND	+	-	-	ND	+	-	-	0.11×10^6	+	+	+	2.3×10^6	+	+	+
Stab 8/3	8.50×10^9	ND	+	-	-	ND	+	-	-	7.5×10^6	+	+	+	2.4×10^9	+	+	+
Stab 11/16	0.53×10^9	ND	+	-	-	ND	+	-	-	0.03×10^6	+	+	+	2.3×10^3	+	+	+
Plants																	
Treated - Leaf	2.03×10^9	ND	-	-	-	ND	-	-	-	ND	-	-	-	9.2×10^6	+	+	+
Control - Leaf	9.15×10^9	ND	-	-	-	ND	-	-	-	ND	-	-	-	9.6×10^6	+	+	+

[1] All results expressed on a dry weight basis.

*Values expressed as a power of 10 (i.e., 10^4).

**Observations reported as + or -.

ND = none detected.

TABLE 79 (Continued)

Sample Description	Total Aerobic Bact per g Sludge (10^6)	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites																	
Surface	4.95	ND	+	-	-	ND	+	-	-	ND	+	-	-	2,400	+	+	+
20-46 cm	3.57	ND	+	-	-	ND	+	-	-	ND	+	-	-	770	+	+	+
46-61 cm	4.39	ND	+	-	-	ND	+	-	-	ND	+	-	-	4	+	+	+
61-91 cm	10.3	ND	+	-	-	ND	+	-	-	ND	+	-	-	240	+	+	+
91-122 cm	4.08	ND	+	-	-	ND	+	-	-	ND	+	-	-	4	+	+	+
Soils - Control Composites																	
Surface	8.04	ND	+	-	-	ND	+	-	-	ND	+	-	-	240	+	+	+
20-46 cm	3.71	ND	+	-	-	ND	+	-	-	ND	+	-	-	1,600	+	+	+
46-61 cm	2.68	ND	+	-	-	ND	+	-	-	ND	+	-	-	2,500	+	+	+
61-91 cm	6.80	ND	+	-	-	ND	+	-	-	ND	+	-	-	400	+	+	+
91-122 cm	2.68	ND	+	-	-	ND	+	-	-	ND	+	-	-	290	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER VI
HOPKINSVILLE, KENTUCKY

SITE DESCRIPTION

Location

This study site is located approximately 5 km (3 mi) northwest of downtown Hopkinsville, Kentucky. Hopkinsville, the Christian County Seat, is approximately 24 km (15 mi) north of the Tennessee border and about 97 km (60 mi) northwest of Nashville, Tennessee.

The treated plot is located approximately 270 m (300 yd) from the Hopkinsville Wastewater Treatment Plant (STP). The control plot is located approximately 1.5 km (1 mi) to the northeast of the treated plot and 5 km (3 mi) north-northwest of downtown Hopkinsville.

Physical Condition

Farming is the predominant occupation in the area, the principal crops being corn, small grains, hay, tobacco, some truck crops, fruit, and pasture. The farm in which the treated plot is located consists of several fields totaling 21 ha (52 acres). As shown in Figure 60, the sampled plot, fenced on all four sides, measures approximately 91 x 107 m (300 x 350 ft) and is characterized by a slight depression of about 1 m (3 ft) running from southeast to northwest. It is in a gently

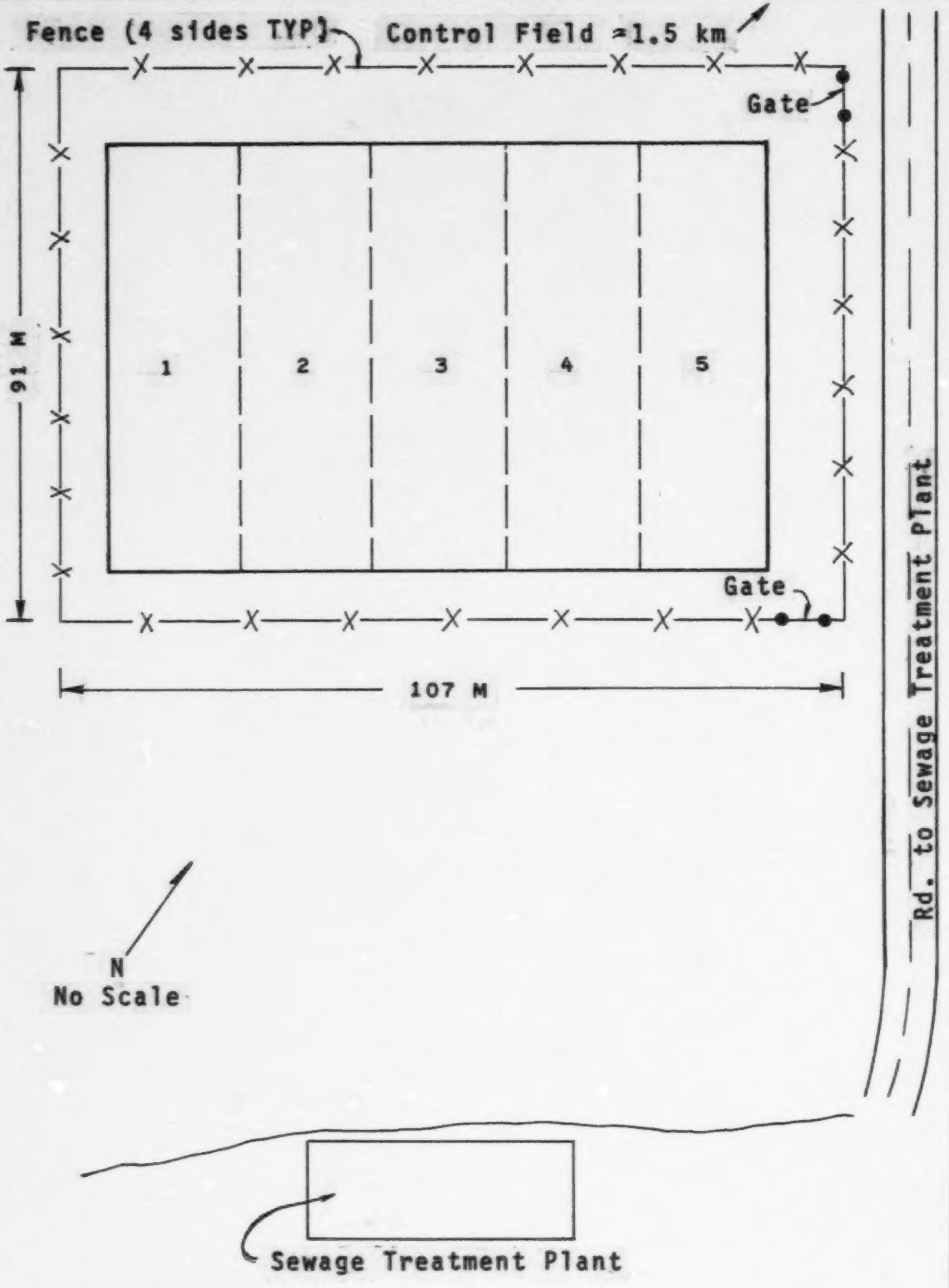

Fence (4 sides TYP)
Control Field ≈1.5 km
Gate
Gate
91 M
1
2
3
4
5
107 M
Rd. to Sewage Treatment Plant
N
No Scale
Sewage Treatment Plant

Figure 60 Hopkinsville, Kentucky Treated Plot

256

rolling slope of less than 2 percent.

The field in which the control plot is located is approximately 12 ha (30 acres) in size. The sampled plot (see Figure 61) measures approximately 91 m (300 ft) square and has topography similar to the treated plot. Plant and soil samples were not taken from the draw shown in the southwest corner of Section 5.

Limestone bedrock and some sandstone exist below both the control and sludge treated plots at a depth of approximately 3 m (9 ft). Depth to groundwater varies with location and season, and no wells exist in the immediate vicinity of either the treated or control plots. The nearest surface water is the North Fork of Little River, located approximately 180 m (200 yds) south of the STP.

Farming Practices

The treated fields are worked by tenant farmers. Sludge has been applied to all 21 ha (52 ac) since 1967, but application rates and uniformity of spreading have not been consistent from field to field.

The approximate 1 ha (2.5 ac) pasture plot selected for sampling first received sludge about 5 years ago when it was applied once every spring for a period of 3 consecutive years. The estimated application rate each time was approximately 22 dry m tons/ha (10 dry tons per ac). Sludge was again applied to this plot on May 12 and 13, 1976 (one week before sampling). An estimated 110 cu m (30,000 gal) of sludge at 10 percent

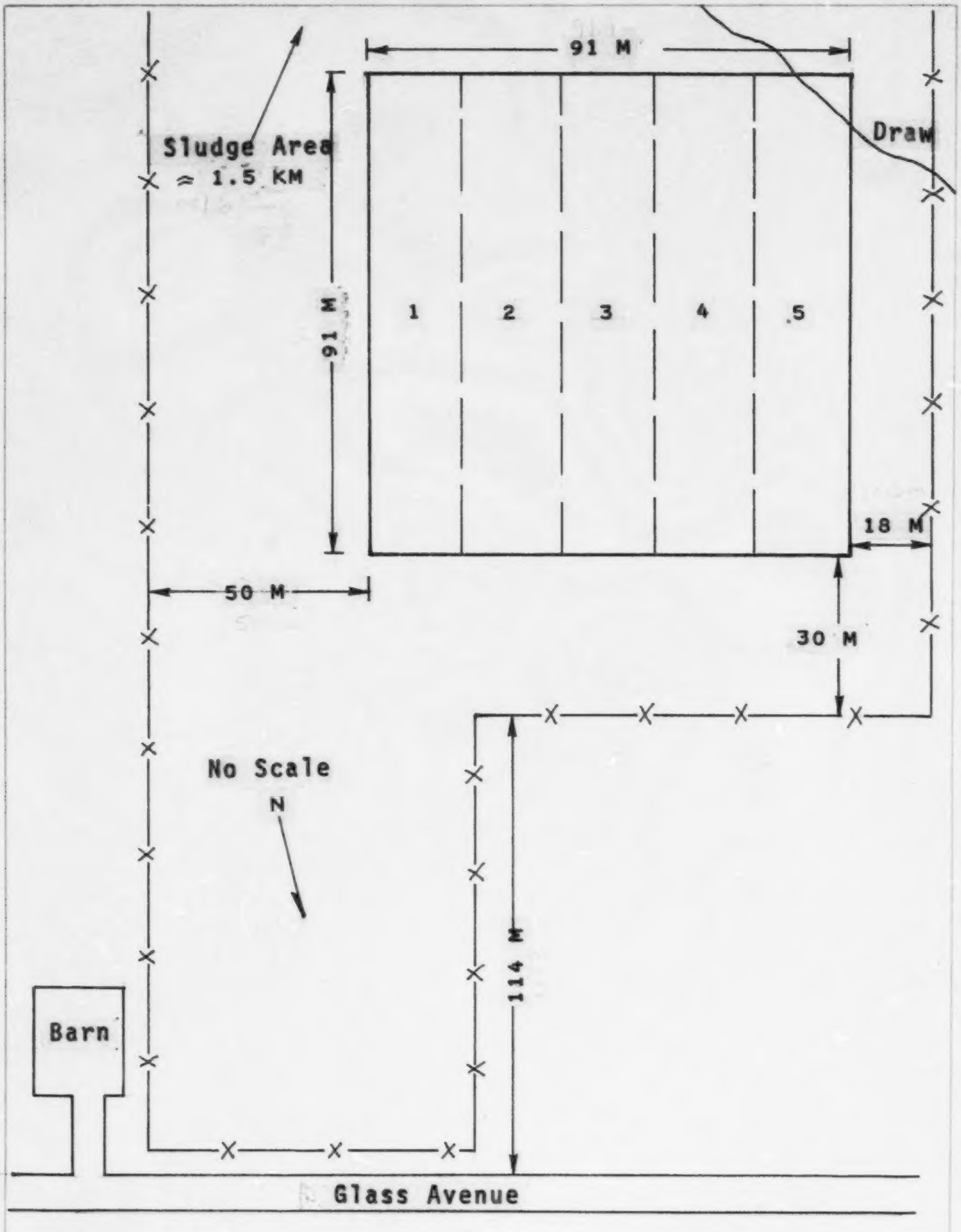

91 M
Sludge Area
≈ 1.5 KM
Draw
91 M
1
2
3
4
5
18 M
50 M
30 M
No Scale
N
114 M
Barn
Glass Avenue

Figure 61 - Hopkinsville, Kentucky Control Plot

solids equivalent to 11 dry m tons/ha (5 dry tons/ac) was spread. Virtually all the sludge applied in 1976 was spread on test Sections 3, 4, and 5 as shown on Figure 60.

At the time of sampling, May 20 and 21, 1976, the treated plot had an abudant crop of common fescue (*Festuca elatior arundinacea*). Other plants such as timothy and orchard grasses, red-top, and clover were also in evidence. Height of fescue was estimated to be about 61 cm (24 in). The farmer indicated that this hay was normally harvested twice each year, once in June and again in late September. The field has occasionally been pastured throughout the years.

The farmer of the treated plot indicated that the plot had been cultivated and planted with crops in one or two years since 1967. However, he could not recall in which years the field had been cultivated and what crops had been grown. Similarly, he indicated that fertilizer had probably been applied to the field at least once since 1967, but could remember neither the year nor the application rate. Lime, at 3.4 m tons/ha (1.5 tons per ac) has been applied once every 3 or 4 years.

For the past 10 to 12 years, the control plot has been used almost exclusively to pasture cattle. Occasionally, the grass in the field has been allowed to grow for a hay crop. As far as the owner could remember, no fertilizer has been applied to the field in the last 10 years. In addition, no herbicides or pesticides have ever been applied.

At the time of sampling (May 20 and 21, 1976), the field was covered with a freshly cut mixture of grasses dominated by tall fescue - the same as on the treated plot.

CLIMATE

The climate of Hopkinsville is temperate with warm, humid summers and moderately cold winters. Passing weather fronts and the associated high and low pressure centers are responsible for the marked weather variations. These fronts are least prevalent in late spring and summer, increase somewhat by late fall, and become most frequent in winter and early spring. The growing season averages 197 days.

Precipitation is fairly well distributed throughout the year, although September and October usually have the least rainfall. Thunderstorms occur approximately 50 days each year. These are most frequent in the spring and summer months. The maximum daily precipitation reflects this short duration, high intensity type of rainfall associated with thunderstorm activity. The mean annual precipitation averages approximately 12 cm (48 in).

Snowfall is quite variable from year to year, with some winters having little or none. The annual average for the period 1896 to 1971 was 27.2 cm (10.7 in). Additional meteorological data are presented in Table 80.

TABLE 80

HOPKINSVILLE, KENTUCKY

LATITUDE 36° 51' N
LONGITUDE 87° 30' W
ELEV. (GROUND) 540 Feet

CLIMATOLOGICAL SUMMARY

REVISED NOVEMBER 1972

MEANS AND EXTREMES FOR PERIOD Extremes: 1896 - 1971
Means : 1942 - 1971

STATION: HOPKINSVILLE,
KENTUCKY

COUNTY: CHRISTIAN

Month	Temperature (°F)							**	Precipitation Totals (Inches)								Mean number of days					Month
	Means			Extremes								Snow, Sleet						Temperatures				
																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Mean degree days	Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year	Precip. .10 inch or more	90° and above	32° and below	32° and below	0° and below	
(a)	30	30	30	75		75		30	30	75		28	75#		41%		30	30	30	30	30	
Jan.	45.2	24.7	35.0	78	1943	-20	1963	930	4.25	5.33	1920	3.8	27.0	1918	7.0	1931	7	0	5	24	1	Jan.
Feb.	49.0	27.1	38.1	82	1962	-22	1951	753	4.24	4.75	1949	2.4	13.2	1921	7.0	1951	7	0	3	20	1	Feb.
Mar.	57.4	34.6	46.0	94	1929	- 3	1960	592	5.30	3.80	1935	2.5	25.7	1960	12.0	1960	8	0	1	14	*	Mar.
Apr.	70.0	46.0	58.0	95	1925	20	1924	226	4.20	6.30	1912	T	5.0	1910	T	1962+	8	*	*	2	0	Apr.
May	78.2	54.6	66.4	100	1911	31	1954	83	4.50	4.00	1905	0	0		0		7	2	0	*	0	May
June	86.4	63.2	74.8	106	1913	40	1956	5	4.07	4.57	1900	0	0		0		6	11	0	0	0	June
July	89.5	65.9	77.7	110	1936	45	1947	0	3.77	4.13	1933	0	0		0		7	17	0	0	0	July
Aug.	89.1	64.6	76.9	111	1930	41	1946	0	3.47	2.93	1949	0	0		0		6	16	0	0	0	Aug.
Sept.	82.9	57.5	70.2	108	1925	31	1899	25	3.07	4.15	1965	0	0		0		5	6	0	0	0	Sept.
Oct.	73.2	45.7	59.5	98	1953	21	1952	217	2.53	5.60	1900	0	1.5	1925	0		4	1	*	2	0	Oct.
Nov.	58.5	35.0	46.8	87	1922	- 4	1950	546	4.11	6.18	1900	0.6	5.3	1906	4.9	1966	6	0	1	14	*	Nov.
Dec.	47.9	27.4	37.7	78	1951	-14	1901	846	4.16	4.75	1902	1.4	18.5	1917	8.0	1963	6	0	3	22	*	Dec.
Year	68.9	45.5	57.2	111	Aug. 1930	-22	Feb. 1951	4223	47.67	6.30	April 1912	10.7	27.0	Jan. 1918	12.0	Mar. 1960	77	53	13	98	2	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

+ Also on earlier dates, months, or years.

* Less than one half.

% 1931-1971 (Some data missing).

# 1896-1971 (Some data missing).

SOIL DESCRIPTION

Regional Area

Most of the land in Hopkinsville, including the treated and control plots, is mapped as the Pembroke series. This soil is typically found on nearly level or sloping (3 to 15 percent) upland areas. Some areas have karst topography.

Soil of the Pembroke series is typically 230 to 300 cm (90 to 120 in) deep, well drained, and moderately permeable with medium runoff characteristics. Silt loam surface layers and silty clay loam subsoils typify the series. These soils were formed, in part, in loess and in part in the underlying limestone residuum or old alluvium under deciduous forests. The original forest was mixed hardwood: chiefly oaks, hickory, maple, ash, elm, hackberry, and poplar. Nearly all the forest has now been cleared; the area is used primarily for crop production.

A typical profile for Pembroke silt loam as mapped by the Soil Conservation Service is described as follows:

- 0 to 22.9 cm (0 to 9 in) - dark brown silt loam; weak to moderate fine granular structure; very friable; many roots; neutral.
- 22.5 to 40.6 cm (9 to 16 in) - reddish-brown to yellowish-red silty clay loam; weak fine subangular blocky structure; friable; many roots; few clay films; common very

263

small black concretions; slight acidic.

. 40.6 to 83.8 cm (16 to 33 in) - red silty clay loam; moderate medium subangular blocky structure; friable; common roots; common clay films; common very small black concretions; medium acidity.

. 83.8 to 114 cm (33 to 45 in) - dark red, heavy silty clay loam; moderate, medium, subangular blocky structure; friable; few roots; common clay films; common black stains in peds; common black concretions; fine, small chert fragments; strongly acidic.

. 114 to 191cm (45 to 75 in) - dark red silty clay; moderate, medium, blocky structure; firm; common clay films; common black stains on peds; common black concretions; fine, small chert fragments; strongly acidic.

...below 274 cm (108 in) - limestone.

Treated Plot

The soil of the treated plot, as sampled, resembled the Pembroke profile as outlined above. Boundaries between the various horizons, however, were wavy, resulting in sampled depths overlapping somewhat the depths presented as the "typical" profile.

Control Plot

Surface and subsurface soil cores sampled from the control plot closely resembled the treated plot soil profile, although the control plot surface horizon was 2.5 to 5 cm (1 to 2 in) thicker than that of the treated plot.

Texture, pH and other related soil data are presented in Table 81.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The Hopkinsville Wastewater Treatment Plant (STP) serves a population of 21,250 (1970) and an equivalent population of 28,710 (1976). The original plant, constructed in 1938, consisted of bar screens, a grit removal basin, primary clarifier, a 37 m (120 ft) dia trickling filter, secondary clarifier, primary anaerobic sludge digester, and sludge drying beds. Sludge from both clarifiers was anaerobically digested, spread in drying beds, and subsequently made available for use by home gardners and a local country club.

In 1958, the treatment plant was expanded by the addition of a second 30 m (100 ft) dia. trickling filter, a sludge thickening tank, and a 890 cu m (235,500 gal) secondary anaerobic sludge digester. No additional changes have been made to the plant since that time.

The present process is as follows: Metered raw sewage is pumped through a bar screen and grit removal chamber before entering the 81 cu m (216,000 gal) capacity primary clarifiers. Detention time is approximately two hours. Secondary treat-

TABLE 81

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

HOPKINSVILLE, KENTUCKY

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N[2]	PH[1]	CEC
			SAND	SILT	CLAY					
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	19.3	1.41	16	62	22	0.037	3.22	16.4	6.2	31
15-30 CM	19.5	0.52	5	64	31	0.046	1.20	0.0	6.2	26
30-61 CM	20.0	0.23	25	55	30	0.043	0.90	2.20	6.0	30
61-91 CM	17.9	0.27	9	63	28	0.004	0.63	0.30	5.3	13
91-122 CM	18.4	0.19	14	56	32	0.321	0.94	1.40	4.8	27
CONTROL										
SURFACE	17.4	1.43	6	67	27	1.23	2.50	14.6	5.2	14
15-30 CM	18.4	0.42	6	62	32	0.031	2.21	11.1	5.6	30
30-61 CM	19.2	0.48	12	45	43	0.067	0.90	3.30	5.7	30
61-91 CM	18.2	0.23	8	56	36	0.032	0.60	48.3	4.7	31
91-122 CM	17.3		8	45	47	0.050	0.60	3.10	4.5	29

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

ment is provided by two rock media trickling filters and 591 cu m (156,000 gal) capacity secondary clarifiers, with a detention time of approximately 1.5 hours. Discharge of treated secondary effluent is to the North Fork of the Little River. No chemicals are added throughout the treatment process.

The present average daily flow is approximately 8,300 cu m/day (2.2 mgd). Design capacity is 11,4000 cu m/day (3 mgd). Table 82 presents treatment efficiencies for a one-year period beginning July, 1975.

An estimated 15 percent of the average daily flow to the STP is derived from industrial sources. The principal industrial contributors are mostly light industries involved in fabrication; their average daily discharges do not vary significantly with the seasons. Table 83 shows, each company, product produced, and average flow.

Data on the industrial contribution of BOD, suspended solids, and oil and grease are not available. The STP superintendent reported that no particular problems have been experienced as a result of the industrial discharges and that the pollutant concentrations are not thought to be significantly higher than for domestic sewage.

Sludge Stabilization and Storage

Sludge stabilization is achieved by two-stage anaerobic digestion. Sludge from the secondary clarifiers is returned to the primaries from which the combined settled sludge is

TABLE 82

HOPKINSVILLE, KENTUCKY - SECONDARY EFFLUENT TREATMENT EFFICIENCIES

Month	Yr.	Average Daily Flow cu m/day	Influent		Effluent		% Reduction	
			BOD (mg/l)	SS (mg/l)	BOD (mg/l)	SS (mg/l)	BOD	SS
July	75	8330	256	204	46	40	82	80
Aug.		8710	317	201	72	32	77	84
Sept.		8710	334	224	68	56	80	79
Oct.		9084	276	199	50	54	82	73
Nov.		9084	240	212	46	51	81	76
Dec.		9460	222	183	50	34	78	81
Jan.	76	9460	190	139	41	16	78	89
Feb.		8710	222	176	45	16	80	91
Mar.		9460	252	211	47	23	81	89
Apr.		8710	242	182	48	30	80	84
May		8710	275	186	43	24	84	87
June		9084	267	348	37	30	86	91
Average		8960	258	205	49	34	81	83

TABLE 83

HOPKINSVILLE, KENTUCKY - INDUSTRIAL FLOWS

Industry	Product	Average flow[1] cu m/day
Ebonite	Bowling balls	197
Faultless Hardware	Plated hardware	151
P. R. Malborn[2]	Tungsten steel powder	643
Mid-Continent	Springs	11
Philips-Dodge	Magnetic wire	170
U.S. Machine	Pop rivets	144
TOTAL		1,316

---

[1] Estimated based upon water consumption figures.

[2] Company recently sold; will be making graphite in the future.

pumped to a sludge thickening tank. From the thickener, the sludge is pumped into the 632 cu m (167,000 gal) capacity primary anaerobic digester. Retention time for the supernatant is normally on the order of a few days, after which it is returned to the primary clarifiers. Retention time of the heavier fraction in the primary digesters is typically on the order of several weeks, after which it is pumped to the secondary sludge digester.

Total retention time in the secondary digester varies widely depending upon seasons. During the spring and summer, when sludge is spread to the maximum extent possible, retention time is approximately one to two weeks. During the winter, however, the retention time may reach three months. Accordingly, sludge solids reportedly fluctuate from a low of two percent (during summer) to a high of 14 percent (prior to spreading in early spring). Additional sludge storage capacity is provided by 11 drying beds, each measuring approximately 30 x 7.5 x 0.5 m (100 x 25 x 1.5 ft).

Chemical analysis of sludge solids has not been performed on a routine basis. The results of two analyses, however, are presented in Table 84.

Disposal of Sewage Sludge

Based on 1971-1975 data, the STP generates approximately 1,780 cu m (470,000 gal) of sludge annually. Assuming an STP reported average solids content of 10 percent, total sludge generated annually is 178 dry m tons (196 dry tons).

TABLE 84

STABILIZED LIQUID SLUDGE ANALYSIS[1]

	Concentration	
Parameter	Test A[2]	Test B[3]
	- ppm -	- u g/g -
Zn	2884	3861
Cu	2156	62.6
Ni	235	271
Pb	918	1617
Cd	17	17.7
Cr	336	-
Volatile Acids	2805	-
Total Alkalinity	2903	-
Moisture (%)	93.5	97.7
pH	5.5	-

[1] Data expressed on an oven dry weight basis.

[2] Kentucky Water Pollution Control Commission, 1971.

[3] Phase I stabilized sludge sample, September 18, 1975.

Approximately 70 to 75 percent of the digested sludge is landspread without dewatering. The remaining sludge is pumped to the drying beds. The bed-dried sludge is used principally by the country club but is also available for local domestic purposes.

Historical records on sludge spreading date back to 1967 when the program was initiated. Table 85 presents available sludge distribution data. In recent years, the amount of sludge spread on the study site has decreased due to more demand by other farmers.

Liquid sludge is spread using a 3.8 cu m (1,000 gal) tank mounted on a 1½ ton truck chassis fitted with a 15 cm (6 in) dia gravity discharge pipe. When applying sludge to a field, the driver brings the truck to a steady speed and opens the sluice gate value at the rear of the tank with a rope in the cab. In this manner, a load of sludge is spread over an area estimated to be 90 m (100 yds) in length and 2 m (6 ft) in width. Assuming approximately 10 percent solids, this is equivalent to a spreading rate of 22 dry m tons/ha (10 dry tons per ac) per application.

Interviews with STP personnel and a tenant farmer indicated no apparent aesthetic or environmental problems associated with this method of sludge disposal. Odors were minimal at the time of field sampling, despite the fact that sludge had been spread only seven days prior to sampling.

Photographs 24 through 27 show, respectively, the

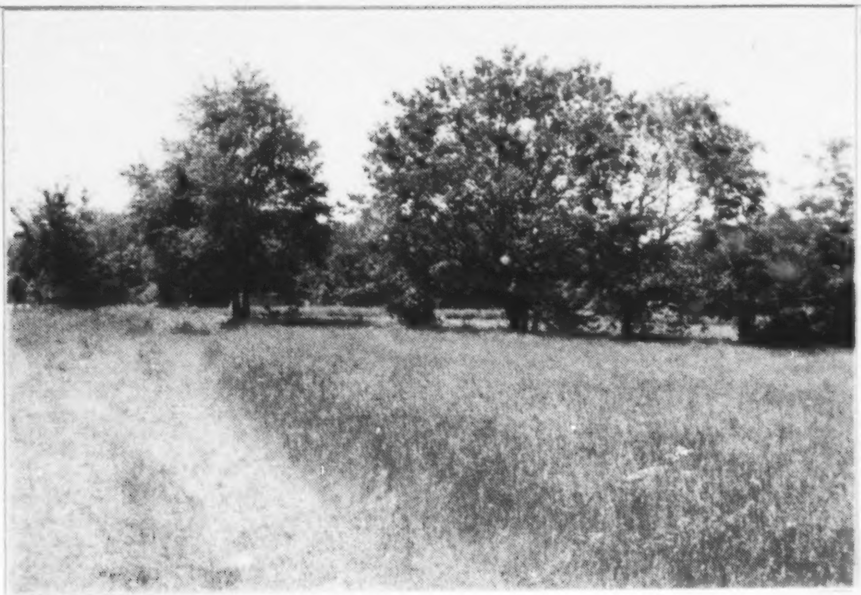
TABLE 85

HOPKINSVILLE, KENTUCKY - SLUDGE GENERATION

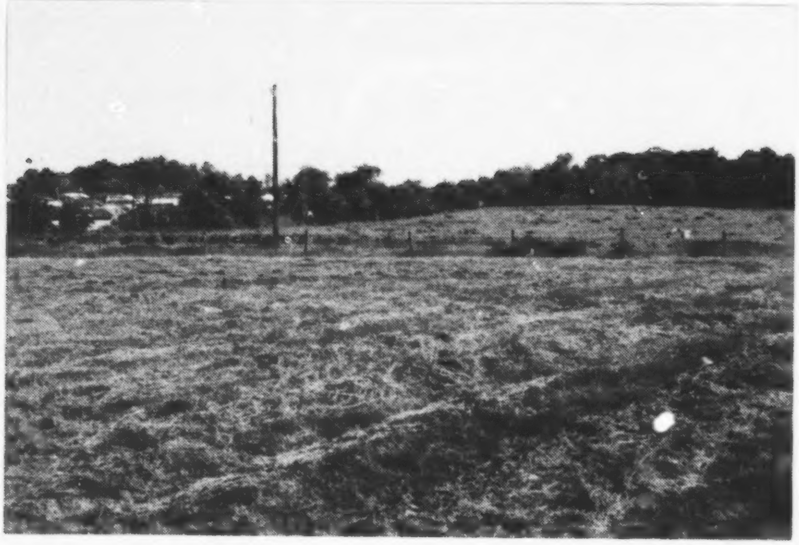
(cu m/yr)

Year	Sludge to Study Site	Total Sludge to All Sites	Sludge to Drying Beds[1]	Total Quantity of Sludge Generated
1967	965	1389	90.8	1480
1968	1136	1226	136	1363
1969	799	935	397	1332
1970	1306	1548	273	1820
1971	1230	---	---	1726
1972	1003	---	---	1616
1973	379	---	---	1809
1974	382	---	---	1639
1975	379	950	1158	2108

[1] Where no values are indicated, the STP records are contradictory.



Photograph 24
Treated Plot



Photograph 25
Control Field

7

Photograph 26
Drying Beds

Photograph 27
Sludge Tank Truck

treated plot, the control plot, the drying beds, and the sludge tank truck.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

The Department of Public Works, the State Department of Health Services, and the local newspaper were contacted to determine public attitudes toward land spreading of sludge.

A representative of the State Department of Health Services stated that they were aware of the sludge spreading practice and that they believed it to be a desirable and acceptable sludge disposal procedure.

A representative of the Public Works Department indicated that they had never encountered opposition to this method of disposal. They also indicated their desire to continue this disposal practice.

When questioned concerning public awareness and attitude towards the land spreading of sludge, the editor of the local newspaper, The Kentucky New Era, indicated that there had never been any articles concerned with sludge disposal methods as far as he could remember. In addition, he could not recall any citizen complaints or objections to the current disposal practice.

Interviews with the local Soil Conservation Service personnel indicated their awareness and acceptance of the sludge spreading practice.

24

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

Representatives of the State Departments of Public Works and Health Services indicated that there were no city, county, or state regulations which affect the current sludge spreading operation at the Hopkinsville site. In addition, there are no requirements for site preparation, monitoring, or specific disposal practices. The STP employees do not receive innoculations as a consequence of their job specialty.

ECONOMICS

Equipment Description and Cost

Total capital investment for the sludge spreading system was approximately $5,000. In 1966, the plant purchased a used 1½ ton Chevrolet truck for $750. A 3.8 cu m (1,000 gal) tank was purchased for $1,000 and mounted on the truck. In 1969, the original truck was replaced with a new 1½ ton Chevrolet truck chassis for approximately $3,000. The sludge tank was transferred from the old truck to the new truck at a nominal cost. The only additional expense for the sludge spreading operation was $50 in materials to facilitate loading of the sludge spreading truck from the existing sludge piping system to the drying beds.

Separate O&M records for sludge spreading are not recorded by the STP. Maintenance costs for the truck, including fuel and repairs, are estimated at $0.20 per mile. Since a majority of the liquid sludge which is trucked from the plant is spread on agricultural land within 1.5 km (1 mi) of the plant, the truck only logs approximately 3,200 km (2,000 mi) a year.

One plant employee is assigned part-time to hauling sludge. The STP superintendent estimates that on the average, it takes one hour to load, haul, and spread a tank load of sludge. Based upon an hourly wage of $3.50 per hour, plus fringe benefits of 25 percent, the labor costs for spreading 250 loads in 1975 were $1,120.

Table 86 provides an analysis of the 1975 (calendar) cost of sludge spreading.

SAMPLING AND ANALYSIS

Sludge

On May 20 and August 25, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the secondary digester.

Soil

On May 20 and 21, 1976, surface and subsurface soil samples were obtained from both the treated and control plots, each of which was divided into five sections. Approximately 20 surface samples were randomly taken throughout each section from the surface 0 to 15 cm (0 to 6 in) with a 2.5 cm (1 in) diameter stainless split tube sampler. Before each core was removed, dead plant material and/or accumulated dried sludge was discarded.

TABLE 86

COST FOR DISPOSAL OF LIQUID SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation[1]			
1969 Chevrolet Truck: $3,000			$ 509
Total Annual Capital Cost			509
Annual Operating Cost			
Personnel	Hourly Rate	% Time Worked	
1 Operator	$3.50	12.6	$ 816
Fringe Benefits (25 percent)			204
Vehicle Maintenance and Operation			400
Total Annual Operating Cost			$1,420
Total Annual Capital and Operating Cost			$1,929
10 Percent Contingency Factor[2]			193
Total Annual Cost			$2,122

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$2{,}122}{\text{105 dry tons}} = \frac{\$22.28/\text{dry m ton}}{(\$20.21/\text{dry ton})}$$

---

[1] Vehicle was fully depreciated over 8 years assuming 8 percent interest, equivalent to $169.68 per $1,000 annually.

[2] A 10 percent contingency factor is added to cover such items as administrative overhead.

Subsoil samples were obtained with a 7.6 cm (3 in) stainless bucket auger. Samples obtained from the depths between 15 to 30 cm (6 to 12 in) were labeled horizon A; 30 to 61 cm (12 to 24 in), horizon B; 61 to 91 cm (24 to 36 in), horizon C; and 91 to 122 cm (36 to 48 in), horizon D.

Both surface and subsurface soil samples at the control plot were obtained in exactly the same manner as those at the treated plot.

Plants

On May 20, 1976 grass samples from the treated plot were obtained by cutting with a pair of shears. The plants were trimmed about 7.6 cm (3 in) from the ground with each sample containing an estimated 100 to 200 individual blades ranging in length from 30 to 61 cm (12 to 24 in). Approximately 20 such samples were obtained from each section.

The grasses on the control plot had been cut on May 19, 1976 in preparation for baling. Since the cut grasses still lay fresh in the field, samples were collected by simply picking up handfulls of the fescue from 20 different locations in each of the five sections. The size of the samples and the length of the grass collected were approximately the same as those obtained from the treated plot.

Tables 87 through 93 present the following:

Table	Description
87	Chemical Characterization of Stabilized Sludges
88	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
89	Total Metal Concentrations in Individual Subsurface Soil Samples
90	Metal Concentrations in Surface Soils and Plants
91	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
92	Parasites in Sludges, Soils, and Plants
93	Concentrations of Microbes in Sludges, Soils, and Plants

Figures 62 to 71 present particle size analyses of the various soil composites by depth

TABLE 87

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM HOPKINSVILLE, KENTUCKY

	5/20/76	8/25/76	Average
Volatile Solids (%)	45.31	36.8	41.1
NO_3 - N	20	<.41	10.2
NH_4 - N	7708	3087	5398
Organic N	21531	15020	18276
P	7187	24014	15600
K	1583	1041	1312
Na	1427	2473	1950
Ca	53563	71351	62457
Mg	3614	3568	3591
SO_4	<21	n.d.	<10
Cl	250	249	250
Ag	1.10	1.22	1.16
As	1.0	1.28	1.14
B	33.5	30.7	32.1
Cd	8.85	6.35	7.6
Cr	483	277	380
Co	10.3	9.05	9.68
Cu	381	714	548
Fe	4708	10209	7459
Hg	6.04	13.6	9.82
Mn	189	214	202
Mo	8.54	13.7	11.1
Ni	6823	57.1	3440
Pb	50.2	120	85.1
Se	4.06	8.65	6.36
Zn	1647	1290	1469
H_2O (%)	90.4	85.0	87.8
pH	7.5	7.6	

All units in µg/g (unless otherwise noted)

All data expressed on oven dry weight basis

TABLE 88

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

HOPKINSVILLE, KENTUCKY

PLOT/ DEPTH	TOTAL METALS (2) CD	CU	NI	ZN	PB	DTPA EXTRACTABLES CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	1.33	26.3	24.8	109	30.2	0.30	6.12	1.59	17.0
15-30 CM.	0.95	17.7	27.0	68.0	17.7	0.08	1.20	1.10	1.49
30-61 CM.	0.69	18.2	39.2	55.0	23.2	0.07	0.55	1.03	0.48
61-91 CM.	0.84	15.4	26.3	60.4	16.0	0.05	0.54	0.80	0.46
91-122 CM.	0.63	15.4	35.4	60.1	24.2	0.06	0.47	0.70	0.44
CONTROL									
SURFACE	0.83	9.80	21.5	50.2	19.5	0.09	0.79	1.20	0.94
15-30 CM.	0.77	13.7	25.6	62.3	18.0	0.05	0.48	1.10	0.42
30-61 CM.	0.78	16.8	37.2	64.0	39.4	0.08	0.40	1.40	0.39
61-91 CM.	1.02	15.4	26.8	71.6	15.3	0.05	0.50	1.30	0.40
91-122 CM.	0.68	15.4	36.4	78.0	23.6	0.05	0.60	1.30	0.49

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 89

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES(1)

HOPKINSVILLE, KENTUCKY

SECTION/ DEPTH	TREATED				CONTROL			
	CD	CU	NI	ZN	CD	CU	NI	ZN
	µ G/G				µ G/G			
SECTION 1								
15-30 CM.	0.97	17.9	27.7	70.3	0.82	15.2	27.8	63.0
30-61 CM.	0.68	19.0	40.2	61.4	0.61	16.6	37.4	55.0
61-91 CM.	0.88	14.8	26.4	64.9	0.80	15.4	27.3	67.0
91-122 CM.	0.60	15.2	34.9	62.0	0.66	16.6	35.6	70.0
SECTION 2								
15-30 CM.	1.06	18.8	27.9	68.0	0.74	12.4	24.4	58.0
30-61 CM.	0.68	18.1	39.6	58.0	0.63	16.5	35.0	49.0
61-91 CM.	0.88	14.7	24.9	60.0	0.84	15.4	24.1	63.0
91-122 CM.	0.52	15.3	34.2	54.8	0.75	16.5	37.1	69.9
SECTION 3								
15-30 CM.	1.00	18.4	28.1	72.7	0.65	10.6	24.0	53.8
30-61 CM.	0.66	17.7	38.3	54.3	0.82	17.1	40.1	61.0
61-91 CM.	0.80	15.1	25.9	62.0	0.91	13.9	24.9	68.0
91-122 CM.	0.67	16.0	40.7	70.0	0.67	14.7	33.1	69.3
SECTION 4								
15-30 CM.	0.89	17.2	27.8	65.4	0.75	11.9	24.3	69.0
30-61 CM.	0.69	19.2	40.0	55.6	0.77	16.1	38.4	64.0
61-91 CM.	0.79	16.0	25.0	56.6	0.88	14.8	26.7	80.0
91-122 CM.	0.64	16.0	36.8	59.3	0.71	14.6	36.8	87.3
SECTION 5								
15-30 CM.	0.88	16.3	25.9	65.3	0.80	13.1	25.8	78.0
30-61 CM.	0.67	18.2	40.1	56.6	0.77	18.5	41.0	71.3
61-91 CM.	0.84	16.3	26.3	60.0	1.00	16.7	29.2	87.0
91-122 CM.	0.67	16.2	34.8	55.7	0.72	17.3	39.2	104

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

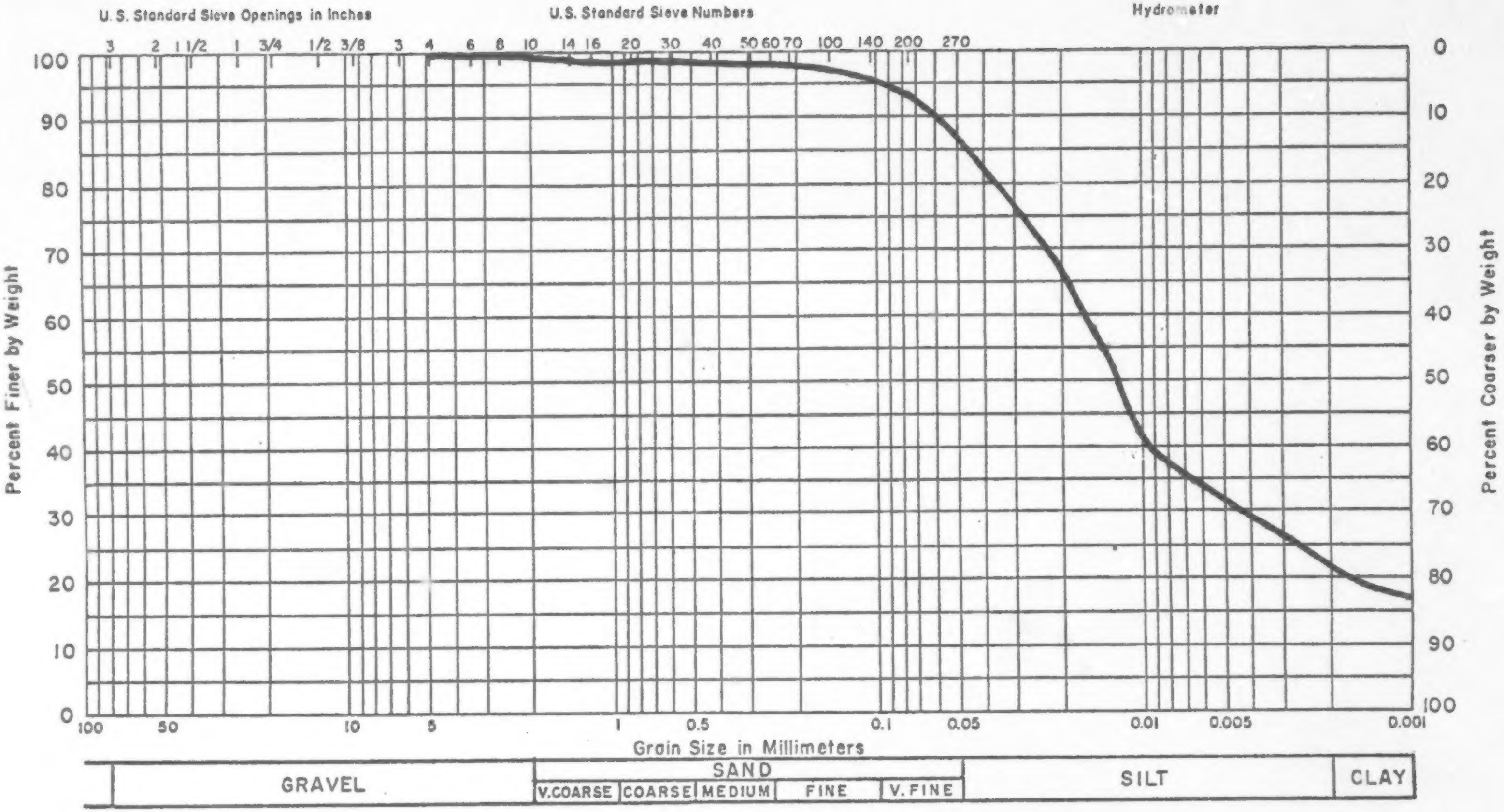
TABLE 90

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS(1)

HOPKINSVILLE, KENTUCKY

SAMPLE	SURFACE SOIL CD	SURFACE SOIL CU	SURFACE SOIL NI	SURFACE SOIL ZN	PB(2)	PLANT CD	PLANT CU	PLANT NI	PLANT ZN	PB(2)	ORG-N(2)
			µG/G					µG/G			
TREATED											
COMPOSITE	1.33	26.3	24.8	109	30.2	0.39	5.39	3.10	31.3	5.08	1.46
SECTION 1	1.33	26.9	24.5	110		0.30	4.63	3.65	27.6		
SECTION 2	0.41	25.4	25.4	107		0.18	4.83	3.89	26.7		
SECTION 3	1.28	25.3	25.0	107		0.39	11.70	6.38	55.3		
SECTION 4	1.37	26.1	25.6	112		0.28	7.50	3.65	40.7		
SECTION 5	1.50	34.8	25.1	117		0.22	7.80	3.83	37.6		
MEAN	1.18	27.7	25.1	111		0.27	7.29	4.28	37.6		
STD. DEV.	0.44	4.02	0.42	4.16		0.08	2.87	1.18	11.64		
CONTROL											
COMPOSITE	0.83	9.80	21.5	50.2	19.5	0.23	4.64	2.70	20.1	4.20	1.25
SECTION 1	0.77	10.7	22.8	47.5		0.25	4.34	2.92	21.4		
SECTION 2	0.86	10.3	22.5	50.4		0.19	4.83	3.81	21.7		
SECTION 3	0.74	8.70	19.9	46.6		0.08	3.64	2.92	17.9		
SECTION 4	0.70	9.20	19.5	49.5		0.14	4.14	3.79	18.4		
SECTION 5	0.83	8.70	18.7	52.2		0.23	4.98	5.10	23.2		
MEAN	0.78	9.52	20.7	49.2		0.18	4.39	3.71	20.5		
STD. DEV.	0.07	0.93	1.85	2.25		0.07	0.54	0.89	2.28		

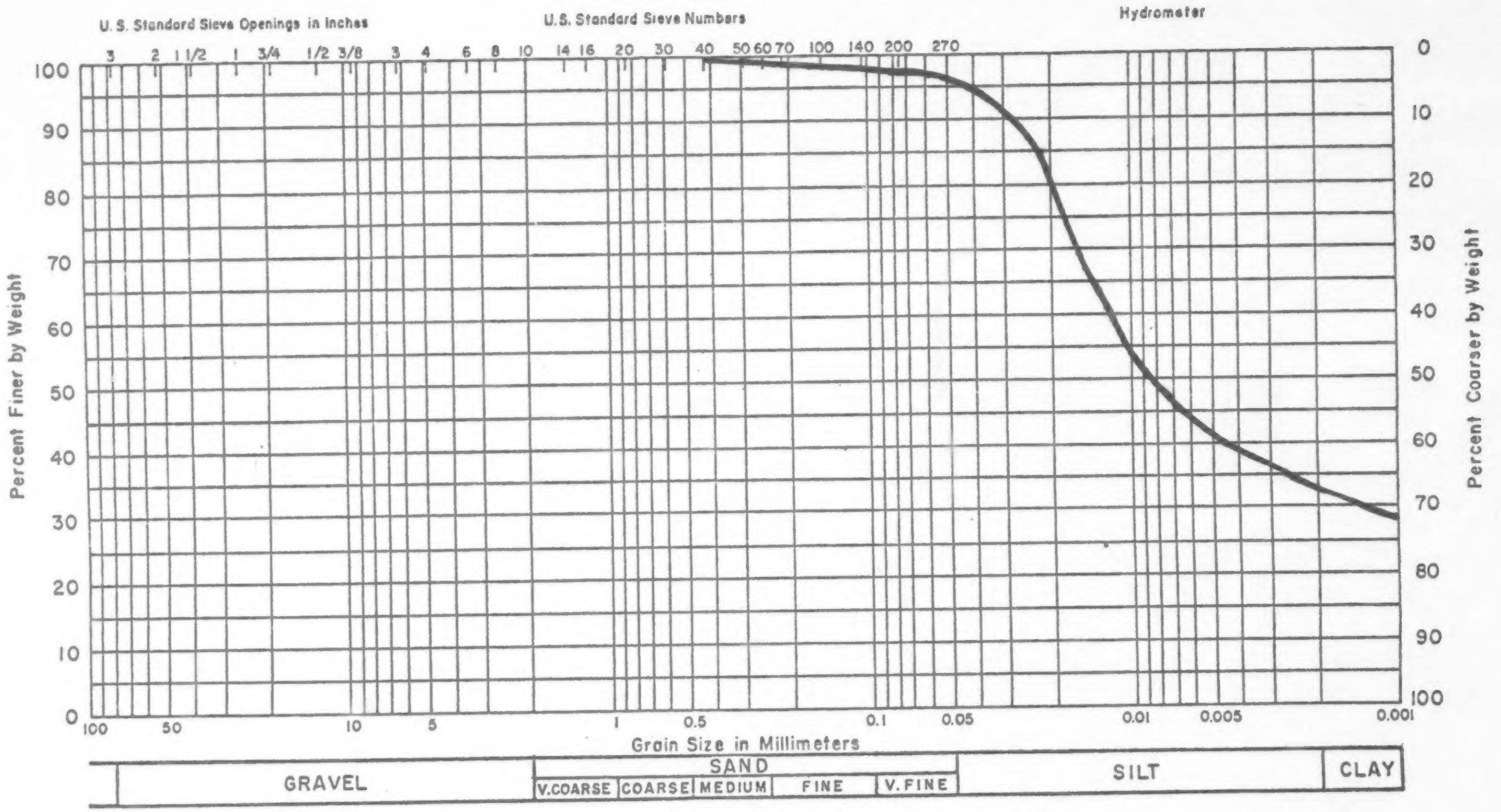
(1) ALL DATA EXPRESSED ON OVEN DRY BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
800	Hopkinsville	16	62	22	Silt Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

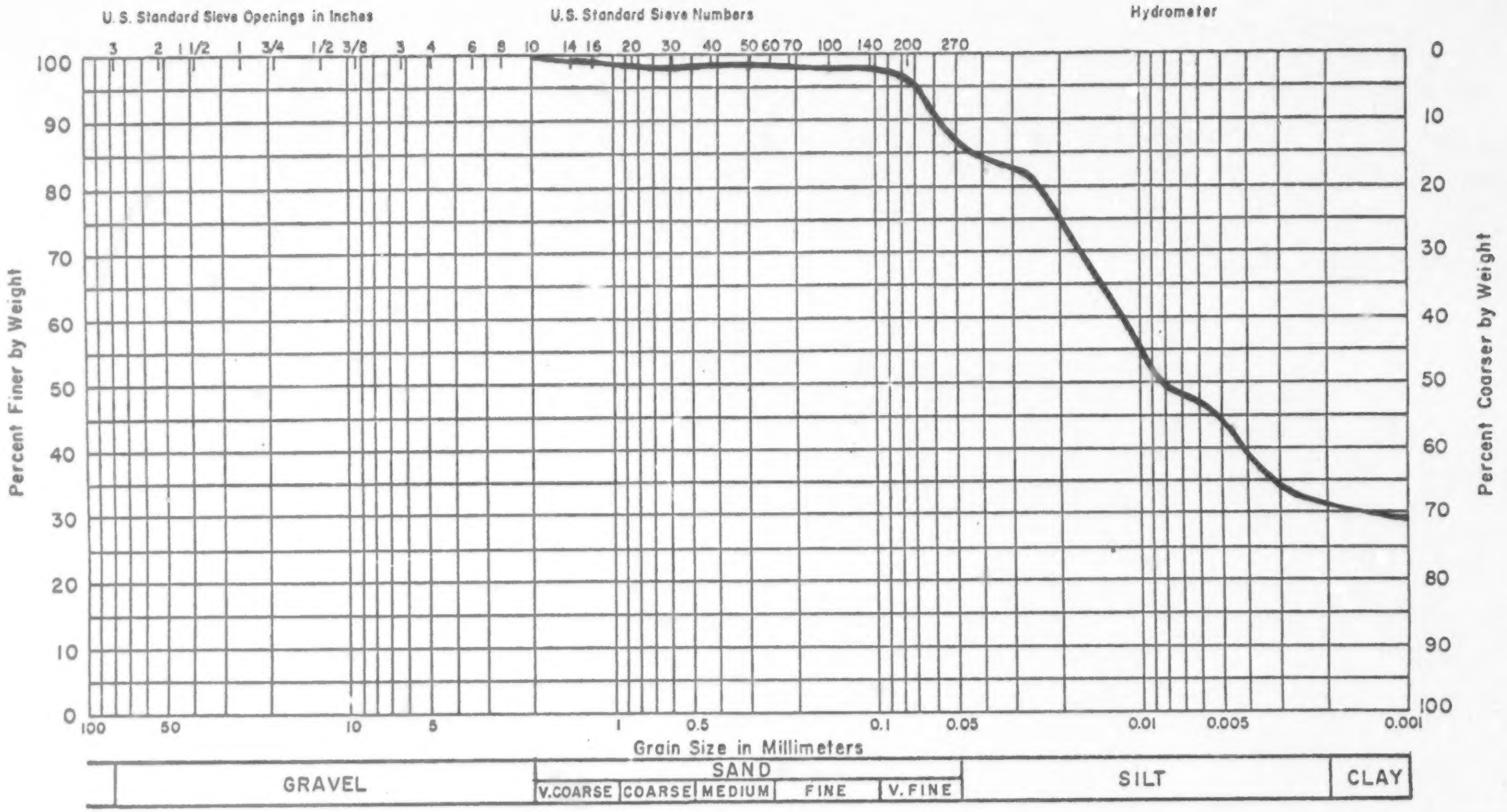
Figure 62 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
806	Hopkinsville	5	64	31	Silty Clay Loam
	Treated				
	15-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

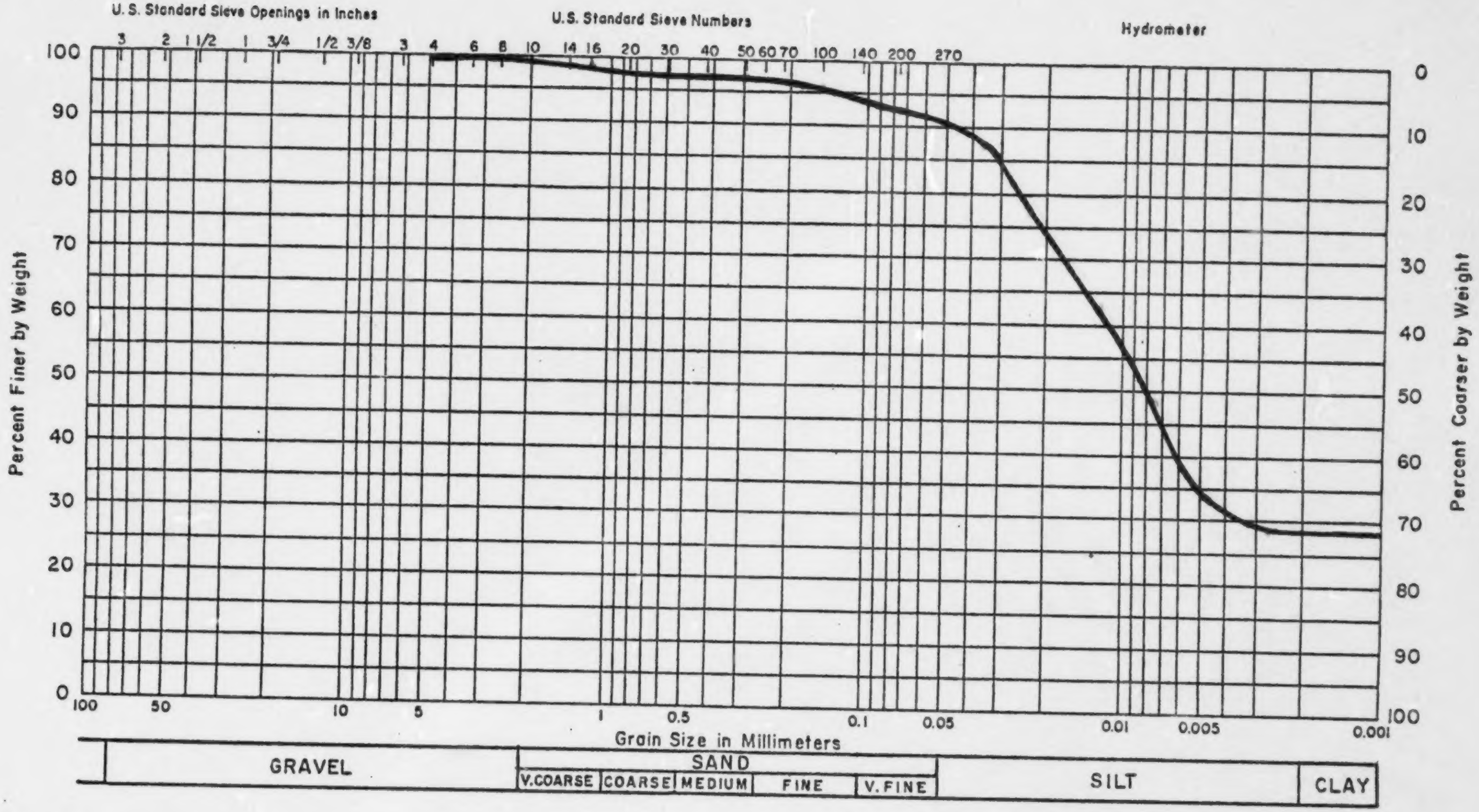
Figure 63 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
812	Hopkinsville	15	55	30	Silty Clay
	Treated				
	30-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

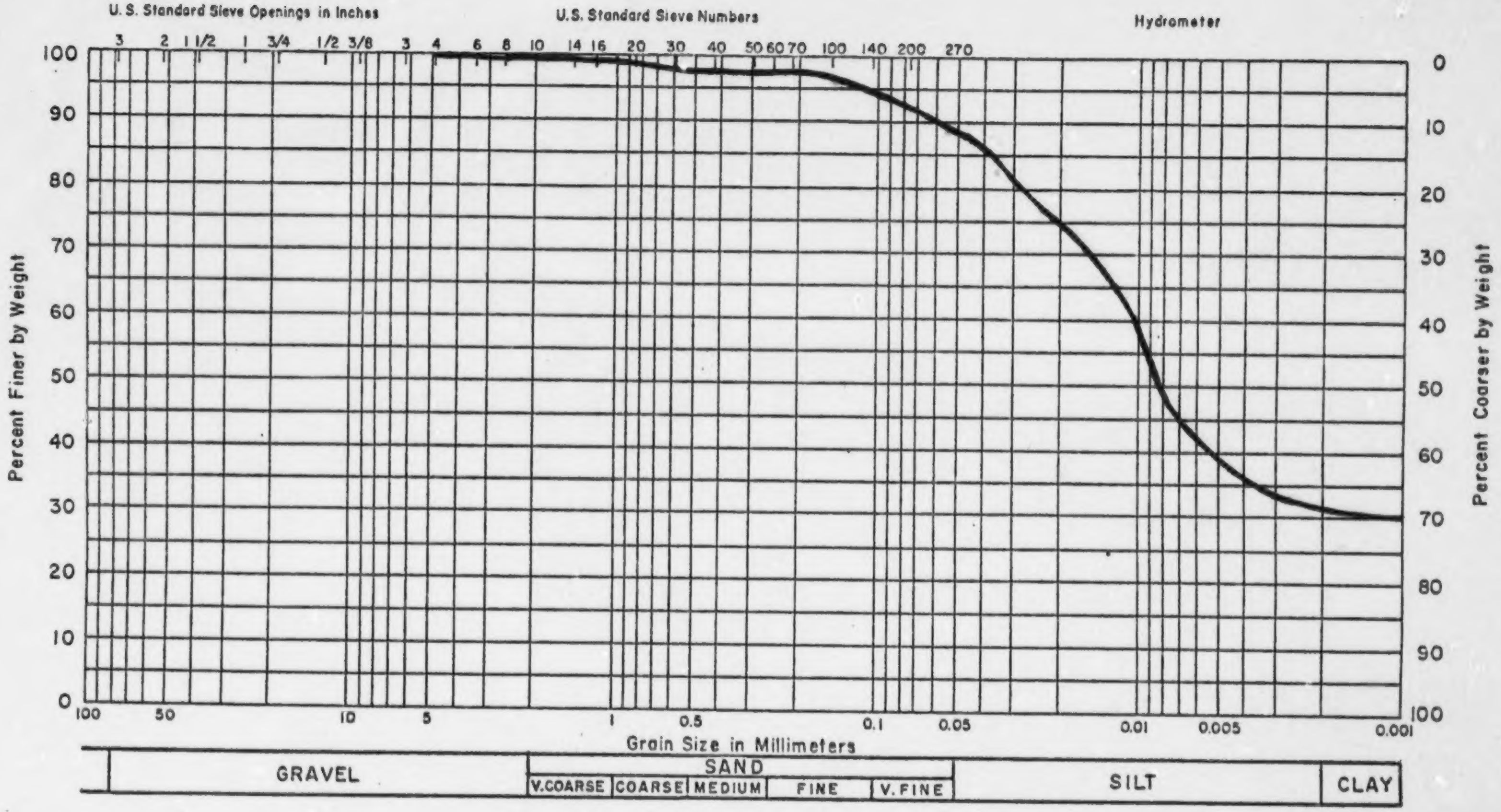
Figure 64 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
818	Hopkinsville	9	63	28	Silty Clay Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 65 Hopkinsville, Kentucky, Particle Size Analysis

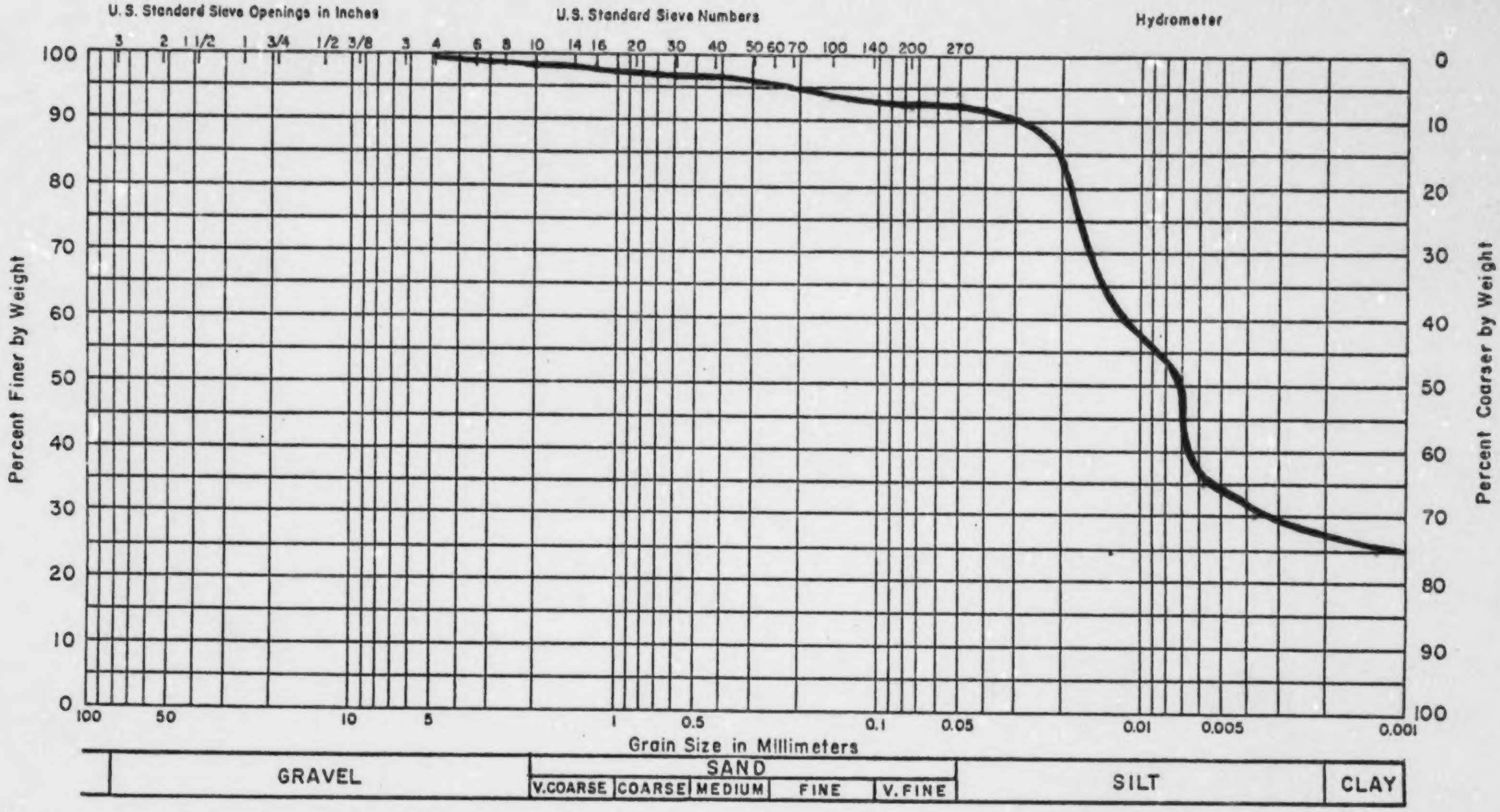


SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
824	Hopkinsville	14	56	32	Silty Clay Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 66 Hopkinsville, Kentucky, Particle Size Analysis

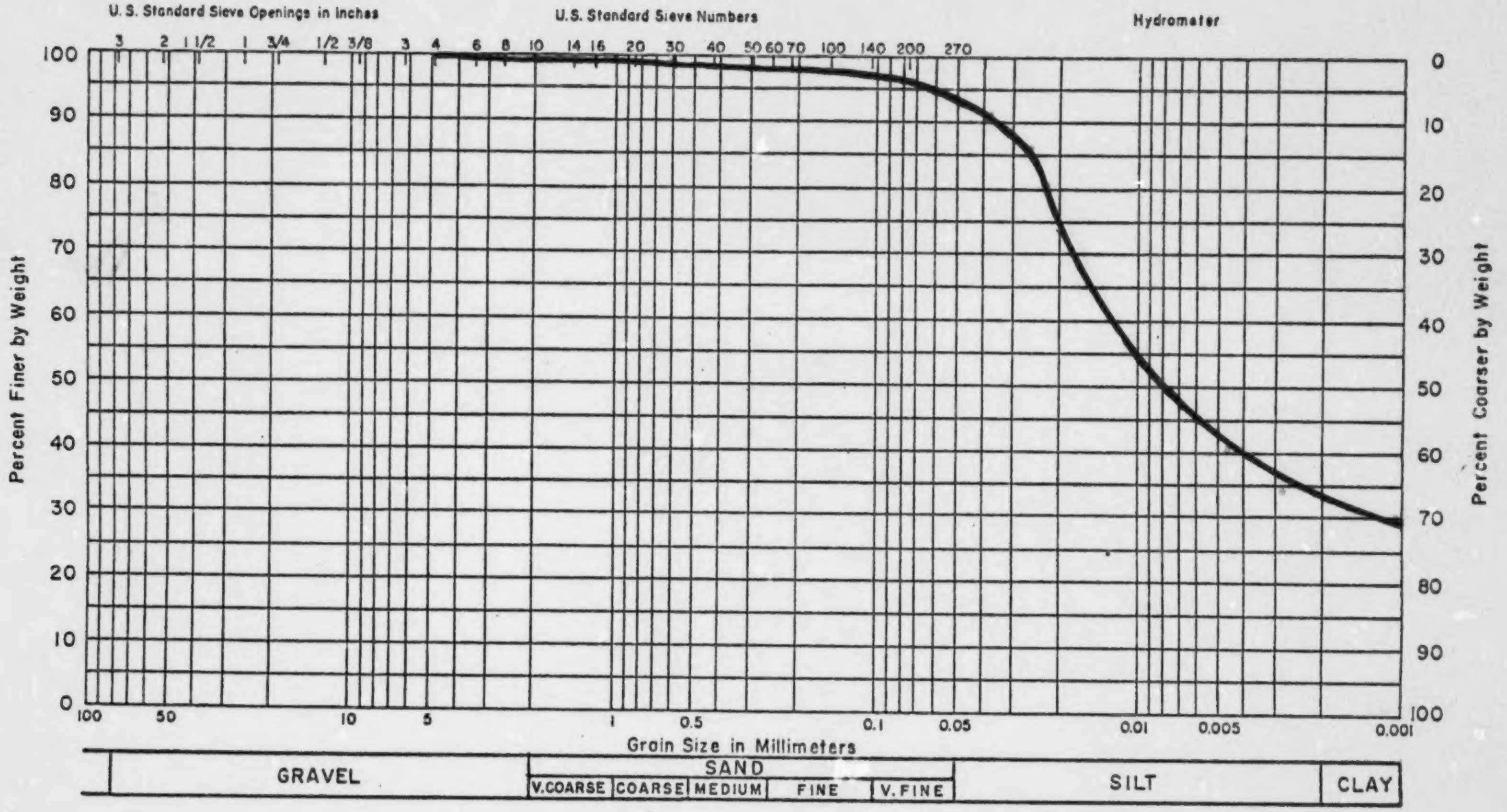
VI-7



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
770	Hopkinsville Control Surface	6	67	27	Silty Clay Loam/Silt Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

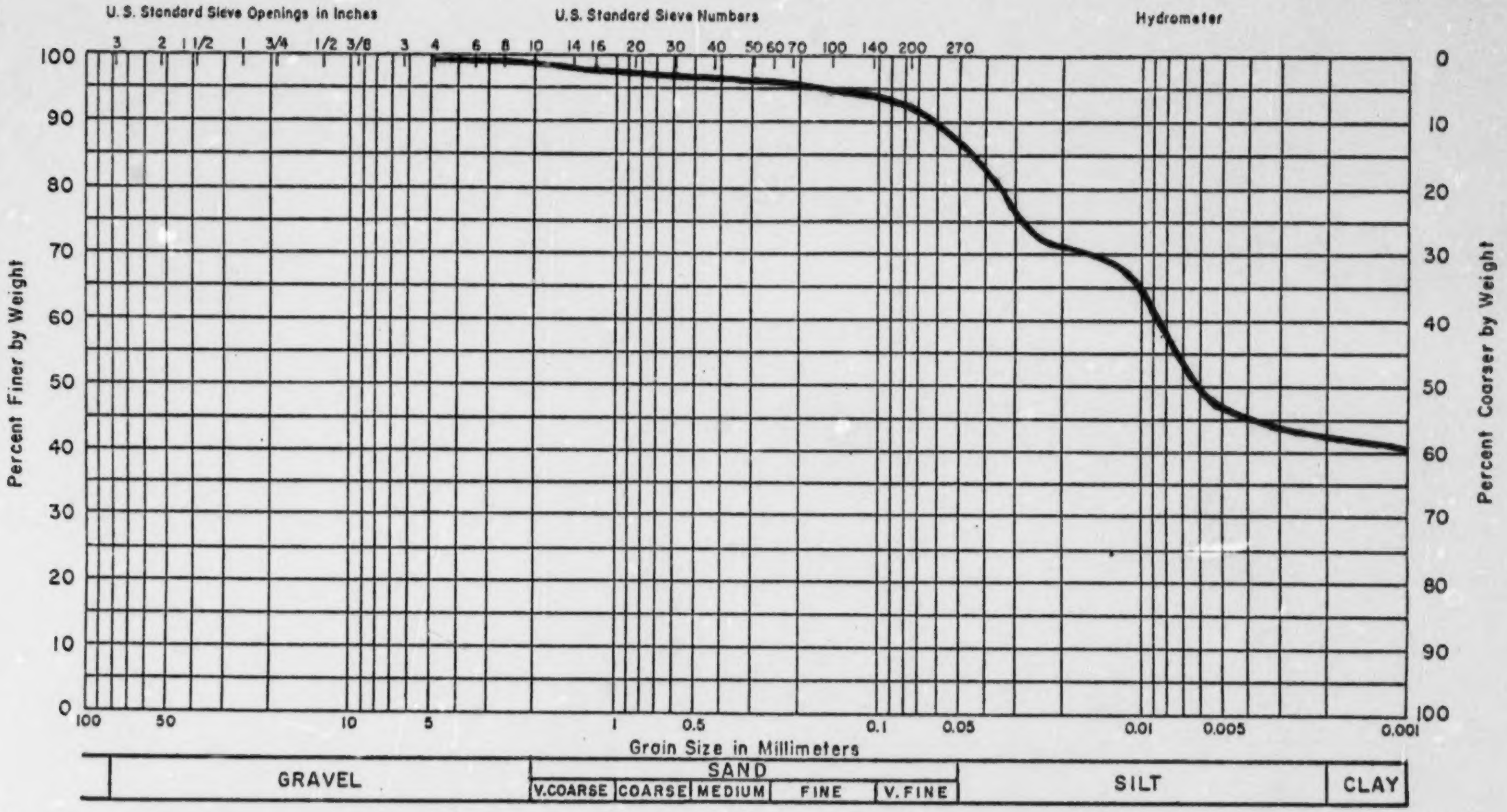
Figure 67 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
776	Hopkinsville	6	62	32	Silty Clay Loam
	Control				
	15-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

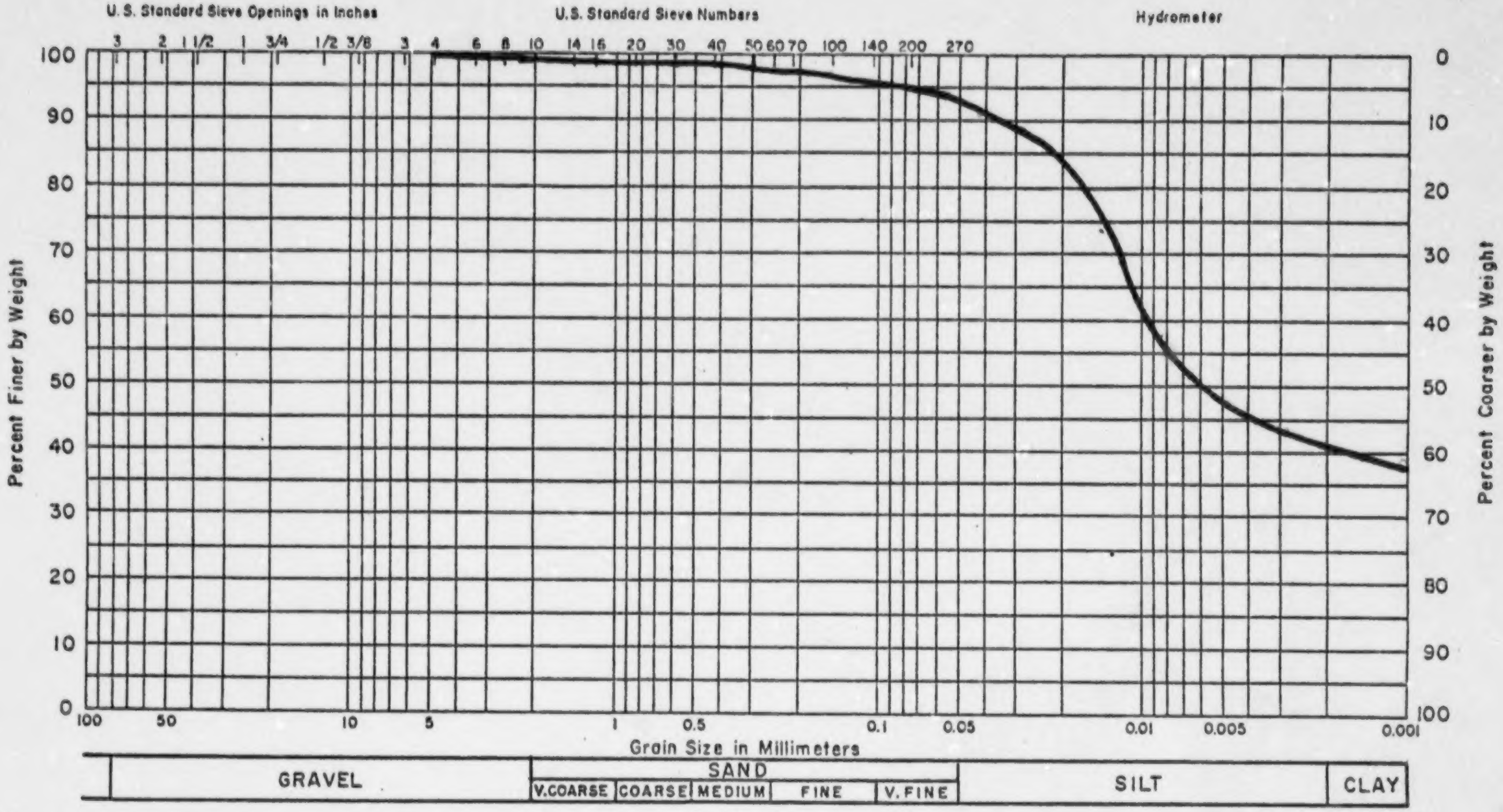
Figure 68 Hopkinsville, Kentucky, Particle Size Ana.ysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
782	Hopkinsville	12	45	43	Silty Clay
	Control				
	30-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

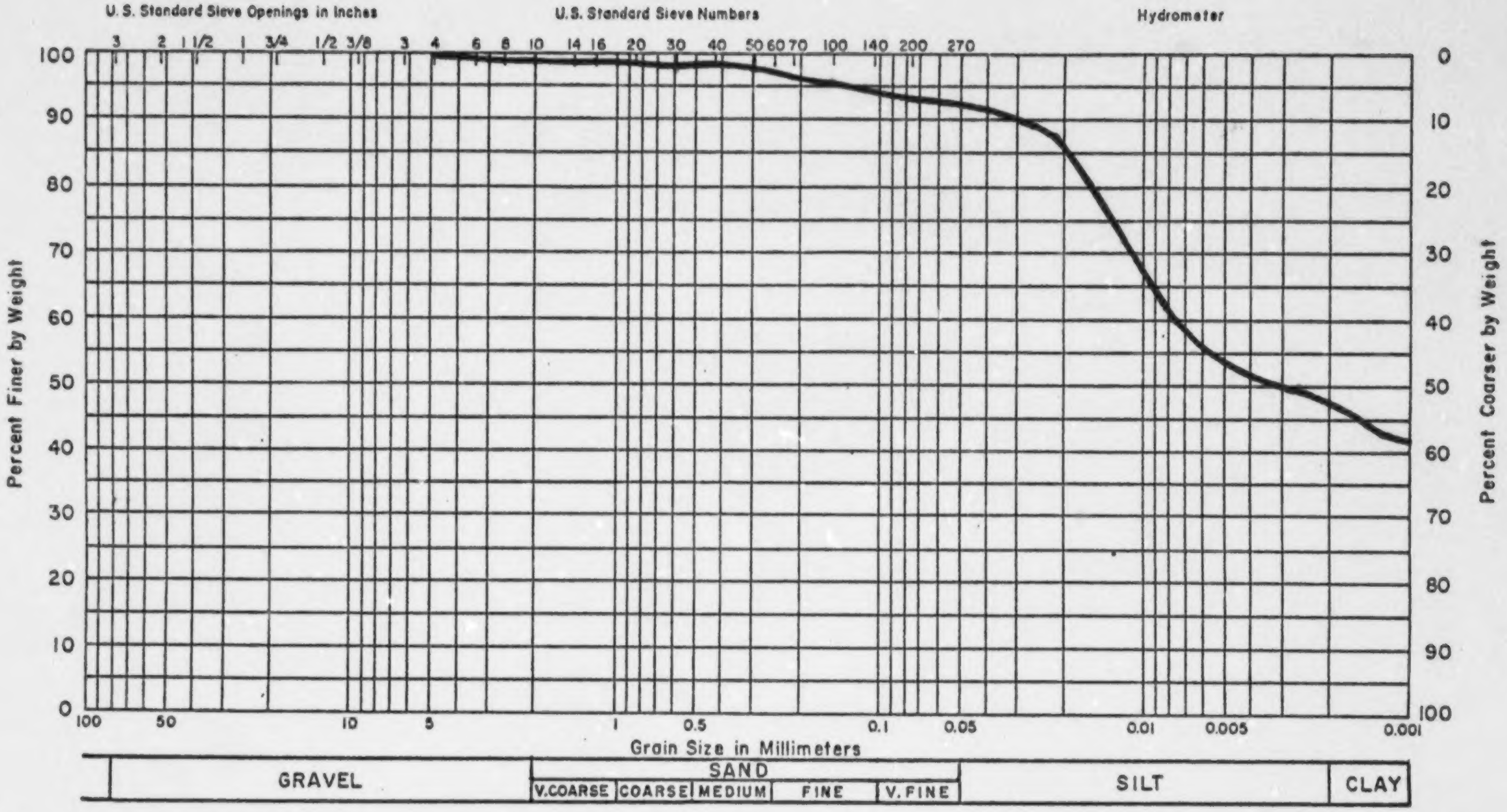
Figure 69 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
788	Hopkinsville	8	56	36	Silty Clay Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 70 Hopkinsville, Kentucky, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
794	Hopkinsville	8	45	47	Silty Clay
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 71 Hopkinsville, Kentucky, Particle Size Analysis

TABLE 91

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

HOPKINSVILLE, KENTUCKY

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . µg/kg	. . . .	
Soil			
Surface Composites	<0.007[1]	<0.007	DDT
	0.47	0.007	DIELDRIN
	<0.75	<0.75	PCB 1221
	<0.5	<0.5	PCB 1248
Plant			
Composites	<0.01	<0.01	DDT
	20[2]	<0.02	DIELDRIN
	<1.17	<0.83	PCB 1221
	<0.11	<0.22	PCB 1248
	(5/20/76)	(8/25/76)	
Stabilized Sludge	9.38	160-p,p^1; 0.4-p	DDT
	14.9	<0.08	DIELDRIN
	260	<.08	PCB 1221
	1469	5837	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

[2] Plant matter interference.

TABLE 92

PARASITES IN SLUDGES, SOILS, AND PLANTS

HOPKINSVILLE, KENTUCKY

Sample Description	Results
Sludge	
Raw (5/20/76)	Ascaris lumbricoides and coccidian occyst - < 50 ova/gram
Raw (8/25/76)	Toxocara canis - < 50 ova/gram
Stabilized (5/20/76)	Negative
Stabilized (8/25/76)	Toxocara canis - < 50 ova/gram
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
15-30 cm	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
15-30 cm	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 93

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
HOPKINSVILLE, KENTUCKY

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 5/20	2.13×10^8	0.83	+	+	+	ND	+	-	-	3.8×10^4	+	+	+	4.0×10^6	+	+	+
Raw 8/25	1.14×10^{11}	ND	+	-	-	ND	+	-	-	3.0×10^3	+	+	+	1.6×10^8	+	+	+
Stab 5/20	9.6×10^6	ND	+	+	-	ND	+	-	-	1.6×10^3	+	+	+	3.0×10^4	+	+	+
Stab 8/25	1.38×10^{10}	ND	+	-	-	ND	+	-	-	3.8×10^3	+	+	+	8.3×10^7	+	+	+
Plants																	
Treated	3.26×10^9	ND	+	+	-	ND	+	+	-	404	+	+	+	1.0×10^4	+	+	+
Control	5.9×10^9	ND	+	+	-	ND	+	+	-	91	+	+	+	4.8×10^4	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

TABLE 93 (Continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites	(10^6)																
Surface	9.62	ND	+	+	-	ND	+	+	-	110	+	+	+	77	+	+	+
15-30 cm	5.49	ND	+	+	-	ND	+	+	-	110	+	+	+	2,900	+	+	+
30-61 cm	5.94	ND	+	+	-	ND	+	+	-	4.7	+	+	+	1,300	+	+	+
61-91 cm	1.40	ND	+	+	-	ND	+	+	-	4.3	+	+	+	2,500	+	+	+
91-122 cm	1.46	ND	+	+	-	ND	+	+	-	11	+	+	+	2,900	+	+	+
Soils - Control Composites																	
Surface	6.91	ND	+	+	-	ND	+	+	-	11	+	+	+	8.6	+	+	+
15-30 cm	4.47	ND	+	+	-	ND	+	+	-	11	+	+	+	13	+	+	+
30-61 cm	0.98	ND	+	+	-	ND	+	+	-	ND	+	+	-	13	+	+	+
61-91 cm	1.9	ND	+	+	-	ND	+	+	-	1,100	+	+	+	11	+	+	+
91-122 cm	1.35	ND	+	+	-	ND	+	+	-	ND	+	-	-	7.3	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER VII

FRANKFORT, INDIANA

SITE DESCRIPTION

Location

This site is located approximately 5 km (3 mi) north of Frankfort, Indiana, and approximately 1.5 km (1 mi) northwest of the Frankfort Wastewater Treatment Plant (STP). The control field is approximately 0.8 km (0.5 mi) north of the treated field.

Physical Condition

Corn, soybeans, and other feed grains compose the principal crops in this area. Native vegetation on this generally flat to gently rolling (slopes less than 4 percent) terrain is typified by dense stands of hardwoods, especially in and around natural drainage courses.

The 2.5 ha (6 acre) treated field (Figure 72) is located on gently rolling terrain at a slightly higher elevation than the level control field. The sampled plot of the treated field is approximately 90 m (300 ft) square, and has a slight depression of approximately 1 m (3 ft) in the northeastern corner of Section 1. Additionally, there is a rise of approximately 1.5 m (5 ft) in Section 5. The field tapers gradually to Wildcat Creek, the principal tributary in the area. This creek forms the southern boundary of the farm. Directly south of Wildcat Creek and across from the treated plot are several large industrial stabilization lagoons which cover a total of

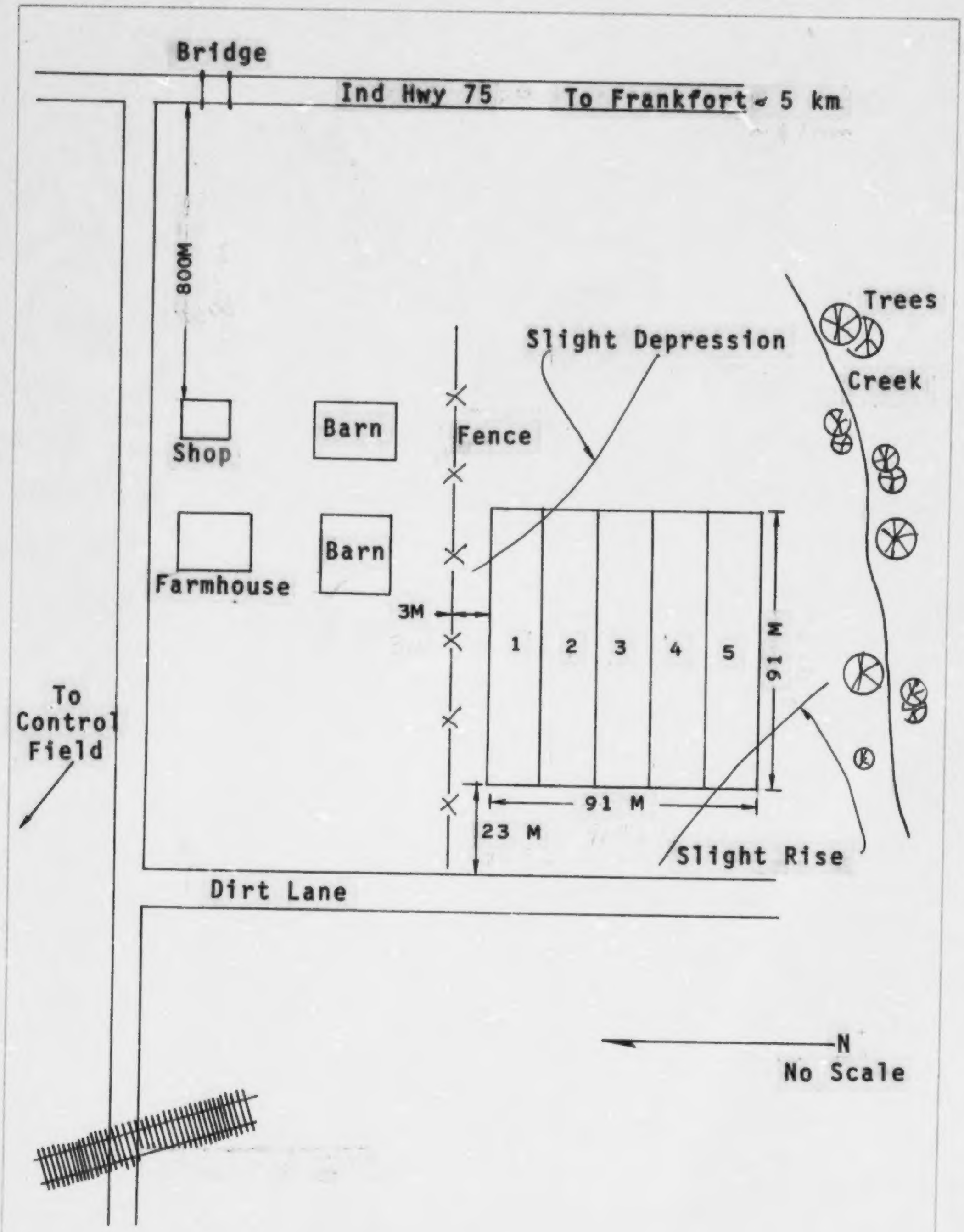

Bridge
Ind Hwy 75
To Frankfort ~ 5 km
800M
Trees
Slight Depression
Creek
Shop
Barn
Fence
Barn
Farmhouse
3M
1
2
3
4
5
91 M
91 M
23 M
To Control Field
Slight Rise
Dirt Lane
N
No Scale

Figure 72
Frankfort, Indiana Treated Plot

300

19 ha (47 acres). These were established by the city to handle the large seasonal effluent from a food cannery.

The sampled control plot, also approximately 90 m (300 ft) square, is located in the southeast corner of an 8.5 ha (25 acre) field north of the treated field (see Figure 73).

Two wells supply all the water to the treated farm. Groundwater is at an estimated depth of 21 m (70 ft).

Farming Practices

The treated field is in a current rotation of two years corn and three years wheat. At the time of sampling (May 25, 1976), the field was in spring wheat (Triticum spp.). The field will be planted to corn in 1977.

This particular field has had a history of continuous sludge spreading dating back to about 1964. Neither the farmer nor STP personnel could recall exactly when and where sludge spreading began, since records were not kept prior to 1974. The farmer estimated that three sludge applications had been made to the total field in 1974 and about one and a half applications in 1975. Estimated application rates, assuming sludge solids of 6.5 percent (STP analytical data), totaled 40 dry m tons/ha (17.7 dry tons/acre) in 1974, and 20 dry m tons/ha (8.9 dry tons/acre) in 1975. The farmer felt that these two years were "typical" in terms of historical sludge application rates. This same farmer also farms another field of approximately 16 ha (40 acres) to which sludge has been applied for the last ten years, but spreading on this field has not

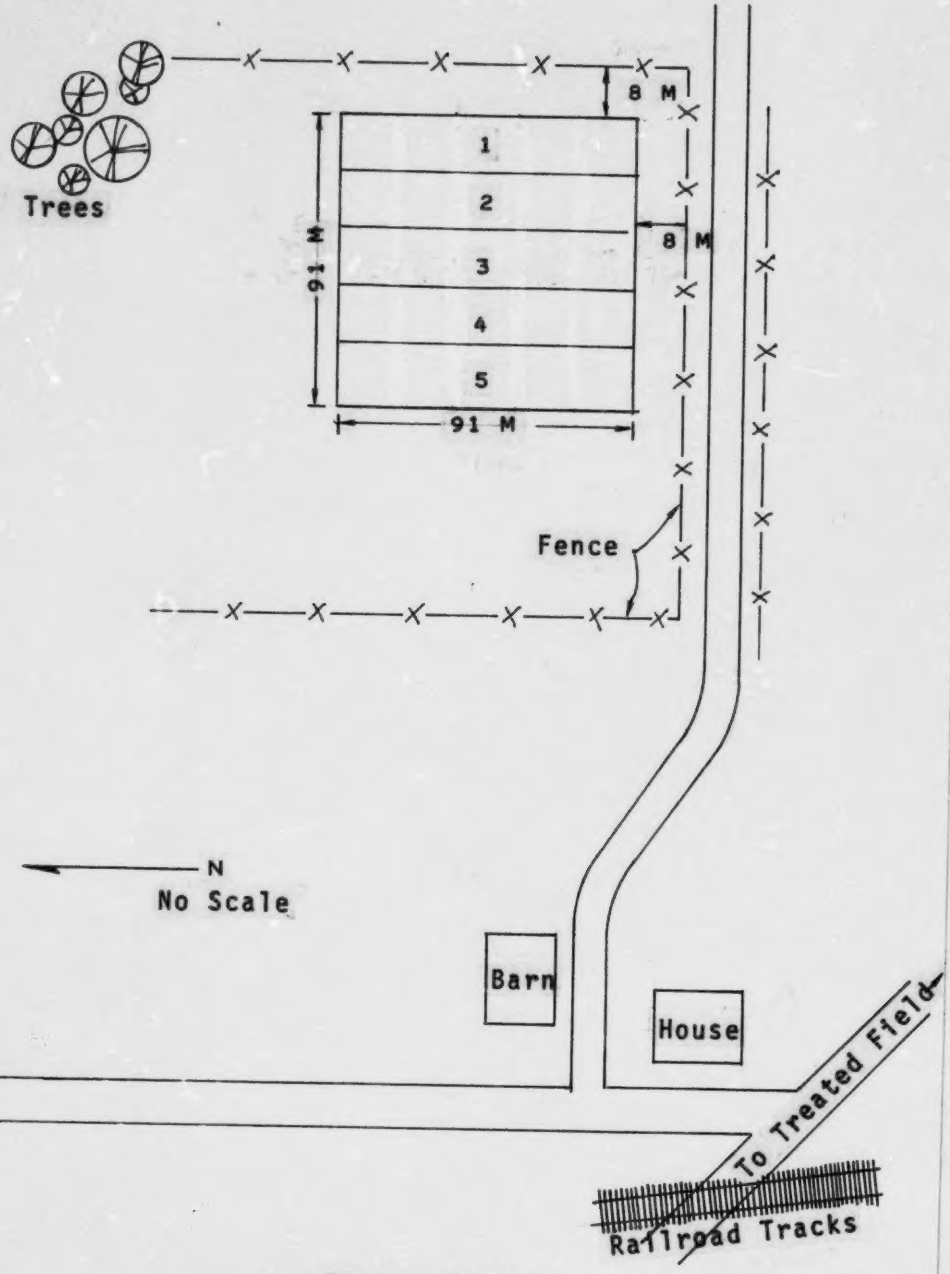

Trees
8 M
1
2
3
4
5
91 M
8 M
91 M
Fence
N
No Scale
Barn
House
To Treated Field
Railroad Tracks

Figure 731-2
Frankfort, Indiana Control Plot

been as consistent as on the smaller field sampled for this study.

Field preparation for wheat usually begins toward the end of September with several applications of sludge. The field stubble is chisel plowed to a depth of 20 to 25 cm (8 to 10 in) and disced, followed by seeding with a grain drill for the next year's crop. Chisel plowing is restricted to shallow depths in order to avoid drain tiles. Lime at 6.7 m tons/ha (3 tons/acre) is incorporated during the field preparation approximately once every three years.

During the wheat cycle, the field is annually supplemented with potash at 220 kg/ha (200 lb/acre). In the spring, 67.2 kg N (ammonium nitrate)/ha (200 lb/acre) is also applied. No other chemicals are used.

Wheat yields were 50, 80 and 64 bu/acre, respectively, for 1974, 1975, and 1976. The farmer has historically sold the wheat crop to a local flour mill.

When the field is prepared for corn (late fall), dry potash at 336 kg/ha (300 lb/acre) is applied, and the field chisel plowed to a depth of 25 cm (10 in). Fertilizer (6-24-24) is then applied at 220 kg/ha (200 lb/acre) in mid-May. Anhydrous ammonia is applied at 110 kg N/ha (100 lb N/acre) to further stimulate crop growth. Atrazine at 4.5 kg/ha (4 lb/acre) is used for weed control after planting.

The control field follows a crop rotation pattern of one year each of wheat, alfalfa/clover, corn, and soy beans. At

304

the time of sampling, this field was planted to the same variety of wheat as the treated field.

Around the first of November, preparation for wheat begins by spreading fertilizer (7-26-26), at 220 kg/ha (200 lb/acre) and discing to a depth of 15 to 20 cm (6 to 8 in). At time of planting (typically, mid-May), the same fertilizer is applied again at 220 kg/ha (200 lb/acre). Additionally, 110 kg/ha (100 lb/acre) of ammonium nitrate is applied in the spring. Lime has been added to the field at 6.7 kg/ha (3 tons/acre), but infrequently - approximately once every four or five years.

For corn, potash at 220 kg/ha (200 lb/acre) and phosphate at 110 kg/ha (100 lb/acre) are added at the time of plowing. When the field is seeded, fertilizer (6-24-24), at 220 kg/ha (200 lb/acre) and anhydrous ammonia at 170 kg/ha (150 lb/acre) are applied. The herbicide, Aatram, is "banded" onto the field at a rate of 9 kg/ha (8 lb/acre).

Wheat yields have historically been between 60 and 70 bu/acre. During the time of sampling (May 24 and 25, 1976), however, the central Indiana area was experiencing a severe drought condition. The wheat, which had formed kernels and was in the milking stage, was yellow to greenish-yellow in color - much more so than the treated field, although neither had been irrigated. The 1976 yield from the control field was 25 bu/acre.

CLIMATE

Precipitation is evenly distributed throughout the year. The month of May usually has more than other months while winter months have the least. Spring and summer rains are usually sufficient for most crops.

Temperatures have ranged in the past 30 years from -30.6 to 24.6^{o}C (-23 to 102^{o}F). July is the warmest month of the year, averaging eight days with temperatures exceeding 32.2^{o}C 90^{o} F). January is the coldest month. Temperatures below zero occur an average of eight days during the winter season.

Snow has occurred as early as October and as late as May, but most falls in February. The greatest snowfall in any one 24-hour period over the last 30 years was 20 cm (8 in) recorded February 25, 1960.

The average freeze-free period extends from April 23 to October 22. However, freezing has occurred as late as May 27 and as early as September 27. Additional meteorological data are presented in Table 94.

SOIL DESCRIPTION

The entire treated plot and the northeast section of the control plot are mapped by the Soil Conservation Service as Russell silt loam. The remainder of the control plot is mapped as Camden silt loam.

Soil of the Russell series is described as gently sloping, deep, and well drained on upland till plains. This soil was formed in 50 to 102 cm (20 to 40 in) of silty loess and underlying glacial till. The dominant slope is about 4 percent. The soil has high available water capacity and moderate permeability. The organic matter content in the surface layer is moderate. Surface water runoff is slow (low spots within

TABLE 94

FRANKFORT, INDIANA

CLIMATOLOGICAL DATA

	Temperature (°F)							**	Precipitation Totals (Inches)								Mean number of days					
	Means			Extremes								Snow, Sleet						Temperatures				
																		Max.		Min.		
Month	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Mean degree days	Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year	Precip. .10 inch or more	90° and above	32° and below	32° and below	0° and below	Month
(a)	30	30	30	30		30		20	30	30		30	30		30		17	30	30	30	30	
Jan.	34.8	17.2	26.0	70	1950	-23	1963	1239	2.23	2.88	1950	5.0	10.0	1964	6.0	1965+	4	0	13	28	4	Jan.
Feb.	37.8	19.5	28.7	69	1944	-20	1963	1024	2.15	2.01	1964	6.0	16.1	1964	8.0	1960	4	0	9	26	2	Feb.
Mar.	47.8	28.1	38.0	79	1967+	-16	1948	861	2.93	2.47	1954	3.7	15.0	1960	4.0	1968+	6	0	3	22	*	Mar.
Apr.	61.8	39.6	50.7	88	1960+	19	1962+	438	4.04	3.16	1964	.3	4.5	1961	3.5	1961	8	0	*	8	0	Apr.
May	72.2	49.7	61.0	94	1964	24	1968	182	4.38	4.45	1943	T	T	1969+	T	1969+	8	1	0	1	0	May
June	81.8	59.0	70.4	100	1944	31	1945	28	4.22	3.47	1958	0	0		0		6	6	0	*	0	June
July	85.2	62.0	73.6	102	1954	42	1947	4	4.13	2.88	1957	0	0		0		7	8	0	0	0	July
Aug.	83.7	59.5	71.6	100	1948	33	1946	14	2.92	3.28	1954	0	0		0		4	6	0	0	0	Aug.
Sept.	77.2	52.1	64.7	99	1953	26	1942	104	3.00	3.92	1950	0	0		0		5	2	0	1	0	Sept.
Oct.	66.6	41.7	54.2	89	1946	17	1962+	362	2.80	2.36	1969	T	T	1967+	T	1967+	5	0	0	7	0	Oct.
Nov.	49.6	31.1	40.4	76	1944	-04	1950	745	2.91	2.40	1958	1.5	5.0	1955	4.0	1955	6	0	2	18	*	Nov.
Dec.	37.7	21.0	29.4	68	1970+	-18	1963	1105	2.21	3.48	1967	4.7	13.0	1960	6.0	1951	6	0	10	27	2	Dec.
Year	61.4	40.0	50.7	102	July 1954	-23	Jan. 1963	6106	37.92	4.45	May 1943	21.2	16.1	Feb. 1964	8.0	Feb. 1960	69	23	37	138	8	**Year**

LATITUDE 40° 19' N.
LONGITUDE 86° 30' W.
ELEV. (GROUND) 833 Ft

(a) Average length of record, years.
T Trace, an amount too small to measure.
** Base 65° and computed from monthly mean temperatures

+ Also on earlier dates, months, or years.
* Less than one half.
Observation time: Midnight

Station: Frankfort, Indiana

fields have been extensively tiled to facilitate drainage). This soil has a friable surface layer that is easily tilled through a wide moisture content range.

The Russell series, as mapped by the Soil Conservation Service, has a typical profile as shown below:

- 0 to 20.3 cm (0 to 8 in) - brown silt loam; friable; moderate, medium, granular structure; neutral.
- 20.3 to 38.1 cm (8 to 15 in) - yellowish-brown silt loam; moderate, fine, subangular blocky structure; friable; patchy brown clay films on faces of some peds; medium acidity.
- 38.1 to 66.0 cm (15 to 26 in) - dark yellowish-brown silty clay loam; moderate, medium subangular blocky structure; firm; continuous dark brown clay films on faces of peds; strongly acidic.
- 66 to 101.6 cm (26 to 40 in) - yellowish-brown clay loam; moderate, medium, subangular blocky structure; firm; continuous dark brown clay films on faces of peds; strongly acidic.
- 101.6 to 121.9 cm (40 to 48 in) - yellowish-brown light clay loam; weak, coarse, subangular blocky structure; friable; discontinuous dark brown clay films on faces of peds; strongly acidic (upper) to neutral (lower).
- 121.9 to 182.9 cm (48 to 72 in) - loam till, massive; very firm; moderately alkaline (calcareous).

Soil of the Camden series, deep and well drained, occurs on upland till plains. This soil was formed in 71 to 140 cm (28 to 55 in) of loess and the underlying outwash. In some areas, the lower part of the profile was formed in the underlying glacial till.

The Camden series has a typical profile as shown below:

- 0 to 22.9 cm (0 to 9 in) - dark brown silt loam; weak, medium structure; friable; neutral.
- 22.9 to 30.5 cm (9 to 12 in) - yellowish-brown silt loam; moderate, medium, platy structure; friable; slightly acidic.
- 30.5 to 40.6 cm (12 to 16 in) - dark brown heavy silt loam; moderate, fine and medium, subangular blocky structure; friable; discontinuous, thin, dark, yellowish-brown coatings on faces of peds; neutral.
- 40.6 to 81.3 cm (16 to 32 in) - yellowish-brown silty clay loam; fine, prismatic structure that parts to moderate, medium, angular and subangular blocky; firm; continuous dark brown clay films; neutral.
- 81.3 to 137.2 cm (32 to 54 in) - dark yellowish-brown silty clay loam; moderate, coarse, subangular blocky structure; firm; continuous dark brown clay films on faces of peds; neutral.

Treated Plot

The sampled surface and subsurface soil closely followed the profile through 122 cm (48 in) as described above for the Russell silt loam.

Control Plot

Similarly, the sampled surface and subsurface soil followed the profile as described for Camden and Russell silt loams. With reference to information supplied by the local Soil Conservation Service, parts of Sections 1 and 2 nearest the fence line (see Figure 73) are mapped as Russell silt loam. Both the Russell and Camden series descriptions are similar; however, differences between soil types were not observed throughout the sampling.

Moisture, pH, and other analytical data for soils of the treated and control plots are presented in Table 95.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The Frankfort Wastewater Treatment Plant (STP) currently serves a population of 15,000 and a population equivalent of 12,900. The latter figure is based on an average (1975) flow of 11,700 cu m/day (3.1 MGD) and a BOD of 85 mg/l.

The STP process, with a design capacity of 13,200 cu m/day (3.5 MGD), has essentially remained unchanged since 1930. Influent to the plant passes through a grit chamber into the primary clarifiers. Detention time in the primaries is approximately two hours. Primary effluent is pumped to a 91 x 30 x 2.4 m (300 x 100 x 8 ft) rock-media trickling filter. Secondary settling tanks, with a detention time of approximately two hours, followed by contact chlorination, constitute final treatment prior to effluent discharge to Prairie Creek. Table 96 presents the STP operating summaries for 1974 and 1975.

TABLE 95

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

FRANKFORT, INDIANA

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS SAND	SILT	CLAY	ORG-N	NO3-N	NH4-N(2)	PH(1)	CEC
	PERCENT						μG/G			MEQ/ 100GMS
TREATED										
SURFACE	6.7	1.48	13	69	18	0.002	1.07	6.50	6.7	30
15-40 CM	9.8	0.86	13	68	19	0.005	0.41	15.1	6.2	26
40-61 CM	12.4	0.70	18	61	21	0.014	1.40	16.0	5.2	25
61-91 CM	13.9	0.38	20	52	28	0.002	0.70	0.40	4.9	18
91-122 CM	15.8	0.41	24	54	22	0.007	2.15	65.0	4.6	30
CONTROL										
SURFACE	5.4	1.22	15	70	15	0.060	1.17	15.1	6.0	13
15-40 CM	10.4	0.67	11	65	24	0.034	1.41	6.30	4.9	30
40-61 CM	13.4	0.40	8	60	32	0.019	0.91	7.00	4.6	26
61-91 CM	15.8	0.30	34	44	22	0.085	1.30	6.60	7.8	14
91-122 CM	15.1	0.28	39	42	19	0.027	1.90	0.0	7.5	12

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 96

FRANKFORT, INDIANA
STP WASTEWATER OPERATING SUMMARIES

Parameter	1975	1974
Average daily flow (cu m/day)	11700	11700
pH	7.2	7.3
BOD - Raw (mg/1)	85	105
BOD - Primary (mg/1)	76	86
BOD - Final (mg/1)	13	16
BOD - Total reduction (%)	84.7	84.8
SS - Raw (mg/1)	38	82
SS - Primary (mg/1)	33	69
SS - Final (mg/1)	13	23
SS - % Total reduction	65.8	72.0
VSS*- Raw (%)	77	67

*VSS - Volatile Suspended Solids

An industrial wastewater surcharge system has been developed and implemented but is presently not enforced. Additional efforts at enforcement are planned in the near future according to STP personnel. Industrial contribution is about 30 percent of total flow.

Only chlorine is added during the treatment process.

Sludge Stabilization and Storage

Raw sludge from the secondary clarifiers and trickling filter is returned to the primaries. Sludge from the primary clarifiers is stabilized in a 2,280 cu m (0.6 MG) anaerobic digester. Supernatant from the digester is returned to the primaries. Maximum detention time in the digester is approximately 45 days. An additional 13 days storage capacity is provided by the two drying beds, each capable of holding approximately 98 cu m (25,000 gal) of sludge.

The STP provided historical sludge analytical data as shown in Table 97. All three stabilized sludge analyses indicate extremely high heavy metal concentrations. On a dry weight basis, cadmium ranged from 1,062 to 2,215 ppm. Similarly, lead varied from 385 to 1,461 ppm.

Industrial contributors to the STP are tabulated in Table 98.

TABLE 97

FRANKFORT, INDIANA - STABILIZED LIQUID SLUDGE ANALYSES[1]

	Concentration						
	Test A[2]		Test B[3]	Test C[4]		Test D[5]	
Parameter	Wet	Dry	Wet	Wet	Dry	Wet	Dry
Cu	52	800	392	2,984	45,000	97.6	3,486
Ni	24	369	3.2	52	800	28.3	1,010
Cr	63	969	16.5	140	2,154	-	-
Cd	69	1,062	33	144	2,215	44.1	1,575
Zn	110	1,692	85	260	4,000	157.5	5,625
Pb	25	385	5	35.6	548	40.9	1,461
P	650	10,000	0	0	0	-	-
Sb	-	-	0.2	1.3	20	-	-
As	-	-	0.02	0.02	-	-	-
Co	-	-	0.75	8.6	133	-	-
Fe	-	-	125	190	2,923	-	-
Mn	-	-	30	20	308	-	-
Mo	-	-	7.6	7.9	122	-	-
Hg	-	-	0	0	0	-	-
Se	-	-	0	0	0	-	-
Moisture[6] (%)	93.5	-	-	93.5	-	97.2	-

[1] All results in ppm.

[2] Indiana State Board of Health (4/21-4/27/75); stabilized sludge.

[3] Clyde Williams and Associates (2/18/76) - raw sludge.

[4] Clyde Williams and Associates (2/18/76) - stabilized sludge.

[5] Phase I stabilized sludge sample, Sept. 26, 1975.

[6] Moisture levels estimated from STP analytical data.

17

TABLE 98

FRANKFORT, INDIANA - INDUSTRIAL FLOWS

Company	Product	Avg. Daily Flow (cu m/day)	Pre-Treatment
Del Monte	Canned Vegetables	No Flow[1]	-
Peter Paul	Candy	814	no
General Battery	Auto Batteries	75.7	yes[2]
Glover Ice Cream	Ice Cream	18.9	no
Indiana Brass	Foundry	378.5	no[3]
Richardson	Porcelain, Enameling	341	no[3]
Mallory Control	Electronics	473	no
Formica	Formica	189	no
National Seal	Gasket, Seal	227	no
Swift	Edible Oils	1741	no

[1] 80 days of tomato processing per year. All flow into special lagoons. Operation to terminate in 1977.

[2] Pretreatment consists of neutralization by lime addition.

[3] Pretreatment facilities currently being installed.

Disposal of Sewage Sludge

Prior to 1964, sludge was vacuum filtered and landfilled. Starting in 1964, however, liquid sludge has been hauled on a continuous and almost exclusive basis to the study site. Accurate records on total amounts disposed have not been maintained. The only recorded totals available were 4,920 cu m (1.3 MG) for 1974, and 4,425 cu m (1.17 MG) for 1975. An additional 665 cu m (175,700 gal) and 292 cu m (77,240 gal) of sludge were distributed in 1975 and 1974, respectively, to the drying beds.

Sludge quantities could not be identified as having been spread on a particular area within the treated fields. As indicated previously, sludge application rates on the sampled plot were estimated to have been 39.6 m tons/ha (17.7 dry tons/acre) in 1974 and 19.9 m tons/ha (8.9 dry tons/acre) in 1975.

Recently, small but unknown amounts of liquid sludge have been spread on the grounds of a large nearby retirement center. The STP personnel also mentioned that whenever the study site could not accept liquid sludge (inclement weather, interference with crops, etc.), the trucks were diverted to ground surrounding the industrial lagoons.

Sludge spreading is accomplished with two trucks. One is equipped with a 6.6 cu m (1,750 gal) tank, the other with a 5.7

cu m (1,500 gal) tank. Sludge is discharged by gravity from a valve attached to the rear of the tank; no special baffle attachments are used. Typically, one tank load covers an approximate 150 x 2 m (500 x 6 ft) area.

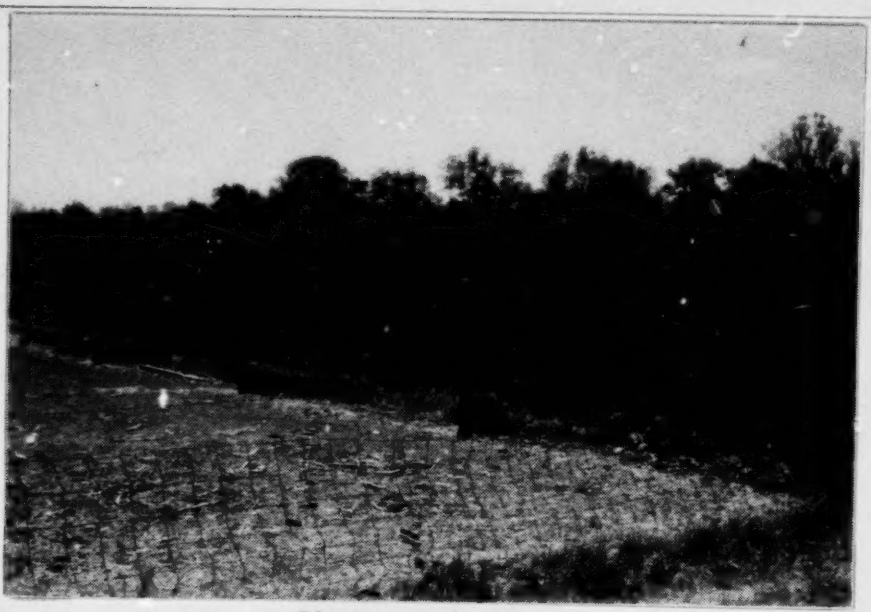
Photographs 28 through 31 show, respectively, the treated field, the control field, the tank truck, and the drying beds.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

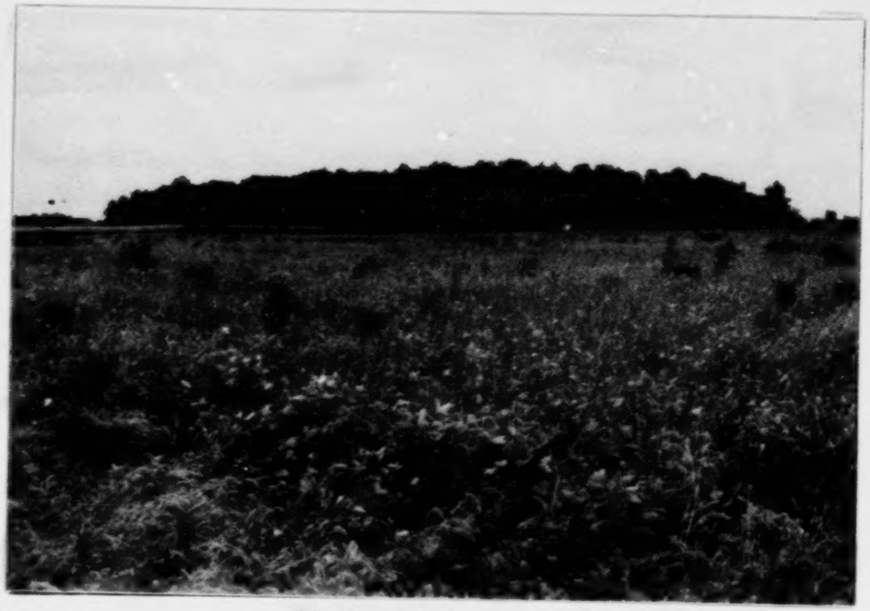
The Clinton County Health Department, the Frankfort Times, and the mayor of Frankfort were interviewed to assess public attitudes and awareness of the local sludge spreading operation. The county sanitarian related his awareness of the practice. He stated that Indiana had no special requirements or permits necessary for the disposal of sludge solids onto farmland. He also stated that he was unaware of any public health problems regarding the handling of sewage sludge.

A member of the Frankfort Times staff could recall only one previous story relative to sludge utilization practices. This was an article printed on September 20, 1975, describing, in general terms, the initial visit of SCS Engineers to obtain Phase I soil, plant, and sludge samples. Following the Phase II samplings of May 24 and 25, 1976, another article appeared relating again, in general terms, the nature of the project. No adverse publicity concerning the sludge spreading program has ever been reported in the newspaper.

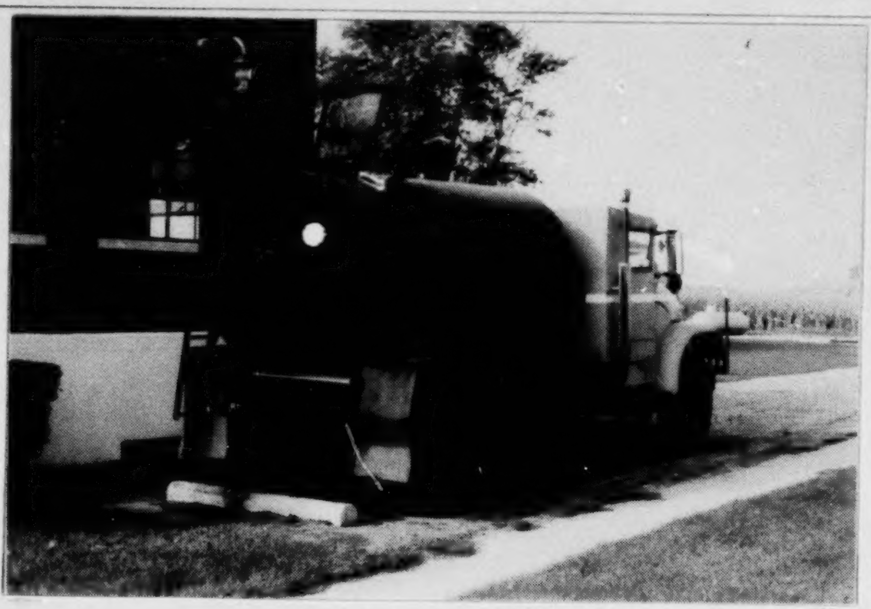
(317)



Photograph 28
Treated Field



Photograph 29
Control Field



Photograph 30
Sludge Tank Truck

Photograph 31
Drying Beds

The mayor of Frankfort similarly related that she was aware of the practice, but could not recall any adverse publicity.

The Frankfort STP superintendent stated that, in his opinion, most people were not aware of the sludge spreading program or of the potential benefits that could be realized from utilizing sludge as a soil amendment. Only one complaint has ever been registered over the use of sludge solids. A neighbor of one of the treated fields objected to the odor when, on one occasion, sludge was spread too close to his farmhouse.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

The STP is not currently governed by any state, county, or city regulations concerning the application of municipal sewage solids to farmland. The county sanitarian mentioned that septic wastes must be plowed into the soil, but that this regulation was not applicable to sludge solids from the STP. STP personnel, when questioned, stated that special permits were not required for disposing of sludge.

The County Health Department is aware of and has given its acceptance to the current sludge handling practices. The STP employees do not receive inoculations, but there have been no reported health problems associated with sludge handling.

The State of Indiana is currently working on the adoption of Guidelines for Sludge Disposal on Land. In May, 1976, Draft #3 - "Interim Guidelines for Municipal Sludge Disposal on Land" was issued. These guidelines are quite similar to those issued by Wisconsin and Ohio and deal with:

- Site selection,
- Allowable total load of sludge on land,
- Allowable sludge application rate,
- Allowable life of disposal site,
- Management of spreading operation, and
- Monitoring and reporting.

ECONOMICS

Record keeping at the STP in terms of sludge generation and cost accounting has been piece-meal. The only recorded investment was a $400 expenditure in 1971 for the purchase of two World War II Army trucks, each subsequently equipped with salvaged tanks for sludge spreading. The trucks, however, remain the property of the U.S. Government, each $200 original "purchase" actually being a life-time lease. One truck is equipped with a 5.6 cu m (1,500 gal) tank, while the second is equipped with a 6.6 cu m (1,750 gal) converted gasoline storage tank.

For estimating costs, the STP superintendent stated that sludge disposal required the services of one operator, 6 hours/day, 3 days/week, 52 weeks/year. The average hauling rate was estimated to be 4 to 5 loads/day at 6.6 cu m (1,750 gal)/load. For bed-dried sludge, it was estimated that five man-days were required to completely remove the sludge from one bed. Throughout calendar 1975, approximately six full beds were removed and made available for local domestic use.

No separate records have been kept relative to O & M costs; consequently, estimates by the STP personnel were made for calendar 1975. These and other related cost data are shown in the cost analysis presented in Table 99. Note that labor for handling bed-dried sludge is included in the analysis.

SAMPLING AND ANALYSIS

Sludge

On May 24 and August 24, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained respectively from both the primary clarifiers and the anaerobic sludge digester.

Soil

On May 24 and 25, 1976, surface and subsurface soil samples were obtained from both the treated and control plots. Each of the plots was divided into five sections. Approximately 30 individual core samples from the surface 0 to 15 cm (0 to 6 in) were obtained from each section with a 2.5 cm (1 in) diameter stainless steel split tube sampler.

Subsurface soil samples were obtained from the treated and control plots with an 8 cm (3 in) diameter stainless steel bucket auger. The surface 15 cm (6 in) of soil was discarded from the auger. Samples were then taken between 15 and 41 cm (6 and 16 in) and labeled Horizon A ; 41 to 61 cm (16 to 24 in) Horizon B ; 61 to 91 cm (24 to 36 in) Horizon C ; and 91 to 122 cm (36 to 48 in) Horizon D.

TABLE 99

COST FOR DISPOSAL OF LIQUID SLUDGE - 1975

Annual Capital Cost			
Vehicle Depreciation			0
Stationary Equipment Depreciation			0
Total Annual Capital Cost			0
Annual Operating Cost			
Personnel (estimated)	Hourly Rate	% Time Worked	
1 Operator - Liquid	$3.26	45	$3,064
1 Operator - Dry	3.26	12	782
Fringe Benefits (25 percent)			962
Vehicle Maintenance and Operation (estimated)			720
Total Annual Operating Cost			$5,528
Total Annual Capital and Operating Cost			5,528
10 Percent Contingency Factor[1]			553
Total Annual Cost (estimated)			$6,081

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$6{,}081}{352 \text{ dry tons}} = \frac{\$19.04/\text{dry m ton}}{(\$17.28/\text{dry ton})} \text{(est.)}$$

---

[1] A 10 percent contingency factor is added to cover such items as administrative overhead.

The extreme eastern edge of Section 1 and the extreme western edge of Section 5 (see Figure 72) of the treated plot were not sampled because of uneven topography.

Plants

Plant samples from the treated and control plots were taken in two steps and in identical manners. At the time of the first sampling, May 24, 1976, wheat in both plots was in the milk to dough stages of the ripening phase. Samples were collected by shearing and retaining the top 20 to 25 cm (8 to 10 in). Approximately ten samplings were made within each section resulting in approximately 1.5 kg (3 lb) of sample per section. The stalks with attached head portions were sent to the laboratory for analyses.

On June 23, 1976, the mature wheat grains were sampled from both plots. Utility shears were used to remove the grains from the plant with approximately 2.5 cm (1 in) of stalk attached. Approximately 1.5 kg (3 lb) of grains were collected from each section. Upon receipt the grain samples were air dried for two weeks, manually threshed and winnowed. The dried wheat grains were submitted to the laboratory for analyses.

Tables 100 through 107 present the following:

Table	Description
100	Chemical Characterization of Stabilized Sludges
101	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
102	Total Metal Concentrations in Individual Subsurface Soil Samples
103	Metal Concentrations in Surface Soils and Plants
104	Metal Concentrations in Wheat Grain Samples
105	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
106	Parasites in Sludges, Soils, and Plants
107	Concentration of Microbes in Sludges, Soils, and Plants

Figures 74-83 present particle size analyses of the various soil composites by depth.

TABLE 100

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM FRANKFORT, INDIANA

	5/24/76	8.24/76	Average
Volatile Solids (%)	48.53	48.05	48.3
NO_3 - N	20.4	6.49	13.4
NH_4 - N	9580	5203	7392
Organic N	25220	20865	23043
P	5492	25919	15705
K	2760	1715	2238
Na	9560	2797	6179
Ca	52200	43000	47600
Mg	3260	7662	5461
SO_4	<20	n.d.	<20
Cl	174	2216	1195
Ag	1.2	2.7	1.95
As	2.6	3.51	3.06
B	65.2	22.0	43.6
Cd	1550	1459	1505
Cr	4074	3905	3990
Co	16	16.4	16.2
Cu	1745	12527	7136
Fe	13280	29595	21438
Hg	8.0	.81	4.41
Mn	247	385	316
Mo	8.4	5.13	6.77
Ni	499	500	500
Pb	103	390	247
Se	5.4	5.95	5.68
Zn	2306	2000	2153
H_2O (%)	95.0	92.6	93.8
pH	7.5	7.1	

All units in µg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 101

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

FRANKFORT, INDIANA

PLOT/ DEPTH:	TOTAL METALS (2) CD	CU	NI	ZN	PB	DTPA EXTRACTABLES CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	12.9	30.0	25.5	88.0	27.8	7.70	5.75	2.78	8.10
15-40 CM.	2.17	15.1	24.5	61.6	16.9	0.87	1.60	1.70	1.74
40-61 CM.	1.05	19.1	34.6	57.0	17.9	0.28	1.15	1.80	1.00
61-91 CM.	0.92	19.1	34.3	56.1	19.9	0.17	1.21	1.70	0.69
91-122 CM.	0.83	22.7	38.5	59.1	18.4	0.13	0.91	1.70	0.61
CONTROL									
SURFACE	0.92	10.6	19.9	49.2	17.2	0.18	1.24	1.87	1.62
15-40 CM.	0.75	15.5	32.6	54.0	21.0	0.08	0.92	1.50	0.60
40-61 CM.	0.80	20.9	37.8	60.8	21.0	0.07	0.90	1.50	0.54
61-91 CM.	0.79	22.0	42.0	57.2	17.3	0.07	0.70	1.50	0.38
91-122 CM.	0.84	22.7	44.5	55.3	18.2	0.07	0.60	1.20	0.38

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 102

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES(1)

FRANKFORT, INDIANA

SECTION/ DEPTH	TREATED				CONTROL			
	CD	CU	NI	ZN	CD	CU	NI	ZN
	µG/G				µG/G			
SECTION 1								
15-40 CM.	1.12	16.4	24.0	62.7	0.84	18.8	36.6	61.0
40-61 CM.	0.87	20.5	38.9	62.0	0.80	23.8	40.8	63.0
61-91 CM.	0.70	18.7	35.3	52.0	0.73	20.5	32.6	51.0
91-122 CM.	0.79	24.1	38.2	58.0	0.72	25.2	41.6	55.6
SECTION 2								
15-40 CM.	1.61	15.3	23.9	62.0	0.76	18.6	32.5	53.0
40-61 CM.	0.87	17.7	34.3	59.9	0.81	22.4	38.9	57.0
61-91 CM.	0.85	20.0	35.3	65.6	0.84	25.1	41.0	60.0
91-122 CM.	0.79	20.1	35.6	57.7	0.99	27.0	53.8	67.0
SECTION 3								
15-40 CM.	4.15	14.9	22.1	61.0	0.81	16.1	32.5	54.0
40-61 CM.	1.10	14.9	29.4	55.0	0.82	22.3	40.6	61.8
61-91 CM.	1.01	15.8	30.6	53.3	1.21	19.7	48.2	52.8
91-122 CM.	0.75	18.1	30.7	55.0	1.23	19.9	54.4	43.4
SECTION 4								
15-40 CM.	2.10	14.3	25.1	66.0	0.73	13.7	29.5	54.0
40-61 CM.	0.96	16.8	31.1	53.0	0.71	16.5	31.9	51.9
61-91 CM.	0.97	21.6	38.2	59.0	0.68	20.7	39.7	55.7
91-122 CM.	0.83	22.1	37.4	58.5	0.70	23.6	44.8	60.2
SECTION 5								
15-40 CM.	2.82	19.3	29.8	68.0	0.76	15.4	31.5	53.6
40-61 CM.	1.61	26.7	43.9	64.0	0.70	17.0	32.5	51.7
61-91 CM.	1.06	24.7	43.2	63.0	1.08	21.4	39.6	62.0
91-122 CM.	0.94	26.9	43.2	64.0	0.71	22.1	41.7	55.8

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 103

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS[1]

FRANKFORT, INDIANA

SAMPLE	SURFACE SOIL					PLANT					
	CD	CU	NI	ZN	PB[2]	CD	CU	NI	ZN	PB[2]	ORG-N[2]
	µG/G					µG/G					
TREATED											
COMPOSITE	12.9	30.0	25.5	88.0	27.8	0.87	6.50	3.61	30.4	1.78	1.95
SECTION 1	4.91	33.0	22.5	71.5		0.85	6.93	3.99	32.3		
SECTION 2	9.51	26.6	25.5	84.4		0.85	6.32	2.85	29.8		
SECTION 3	9.50	23.4	24.5	79.2		0.56	6.68	3.80	28.7		
SECTION 4	18.2	29.9	27.6	87.4		1.01	6.81	2.47	29.3		
SECTION 5	23.3	36.2	30.4	104		1.32	6.99	3.80	28.7		
MEAN	13.1	29.8	26.1	85.3		0.92	6.75	3.38	29.8		
STD. DEV.	7.47	5.06	3.03	12.1		0.28	0.27	0.68	1.49		
CONTROL											
COMPOSITE	0.92	10.6	19.9	49.2	17.2	0.28	5.81	3.99	29.1	1.68	1.68
SECTION 1	0.92	10.8	21.0	50.8		0.27	6.32	5.38	26.7		
SECTION 2	0.90	10.7	19.6	48.3		0.37	5.95	3.99	33.3		
SECTION 3	0.94	10.0	19.2	49.8		0.20	5.95	3.80	27.1		
SECTION 4	0.92	11.4	21.5	53.0		0.20	5.53	3.99	25.8		
SECTION 5	0.90	10.8	19.6	50.4		0.34	5.77	3.61	26.7		
MEAN	0.92	10.7	20.2	50.5		0.28	5.90	4.15	27.92		
STD. DEV.	0.02	0.50	1.01	1.71		0.08	0.29	0.70	3.04		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.

TABLE 104

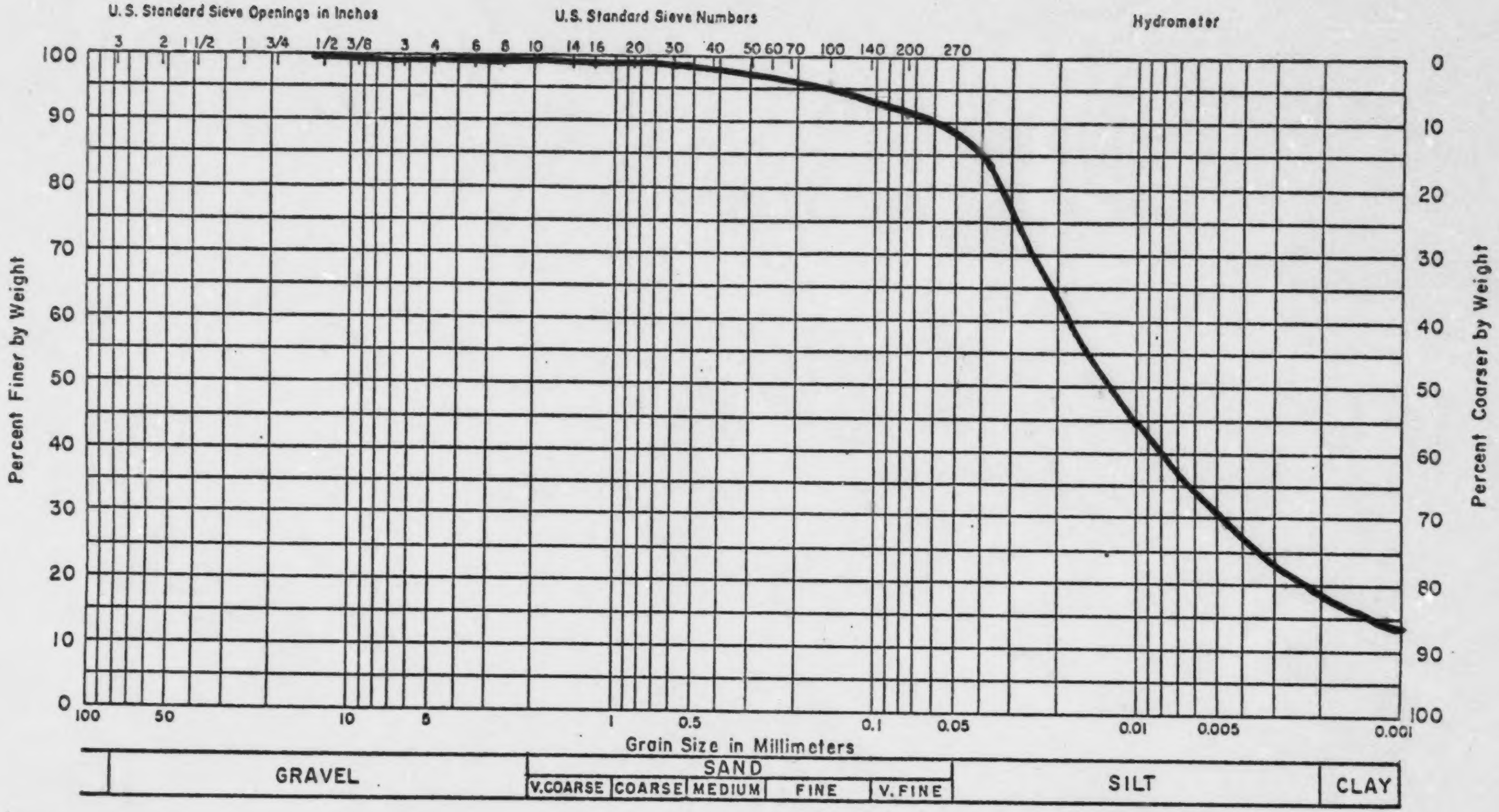
METAL CONCENTRATIONS IN WHEAT GRAIN SAMPLES$^{(1)}$

FRANKFORT, INDIANA

SAMPLE	CD	CU	NI	ZN	PB$^{(2)}$	ORG-N$^{(2)}$
			PLANT			
			µG/G			
TREATED						
COMPOSITE	1.24	4.64	1.34	44.8	0.67	2.33
SECTION 1	0.58	4.16	1.08	40.4		
SECTION 2	1.34	4.68	1.20	45.7		
SECTION 3	1.38	4.83	1.27	51.4		
SECTION 4	1.13	4.55	1.18	44.4		
SECTION 5	1.89	5.01	1.45	43.5		
MEAN	1.26	4.65	1.24	45.1		
STD. DEV.	0.47	0.32	0.14	4.04		
CONTROL						
COMPOSITE	0.20	5.95	1.87	57.0	0.73	2.79
SECTION 1	0.22	6.66	1.88	61.9		
SECTION 2	0.19	6.00	1.85	55.9		
SECTION 3	0.16	5.99	1.57	52.6		
SECTION 4	0.20	5.90	2.18	59.9		
SECTION 5	0.21	6.28	2.41	57.3		
MEAN	0.20	6.17	1.98	57.5		
STD. DEV.	0.02	0.31	0.32	3.60		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

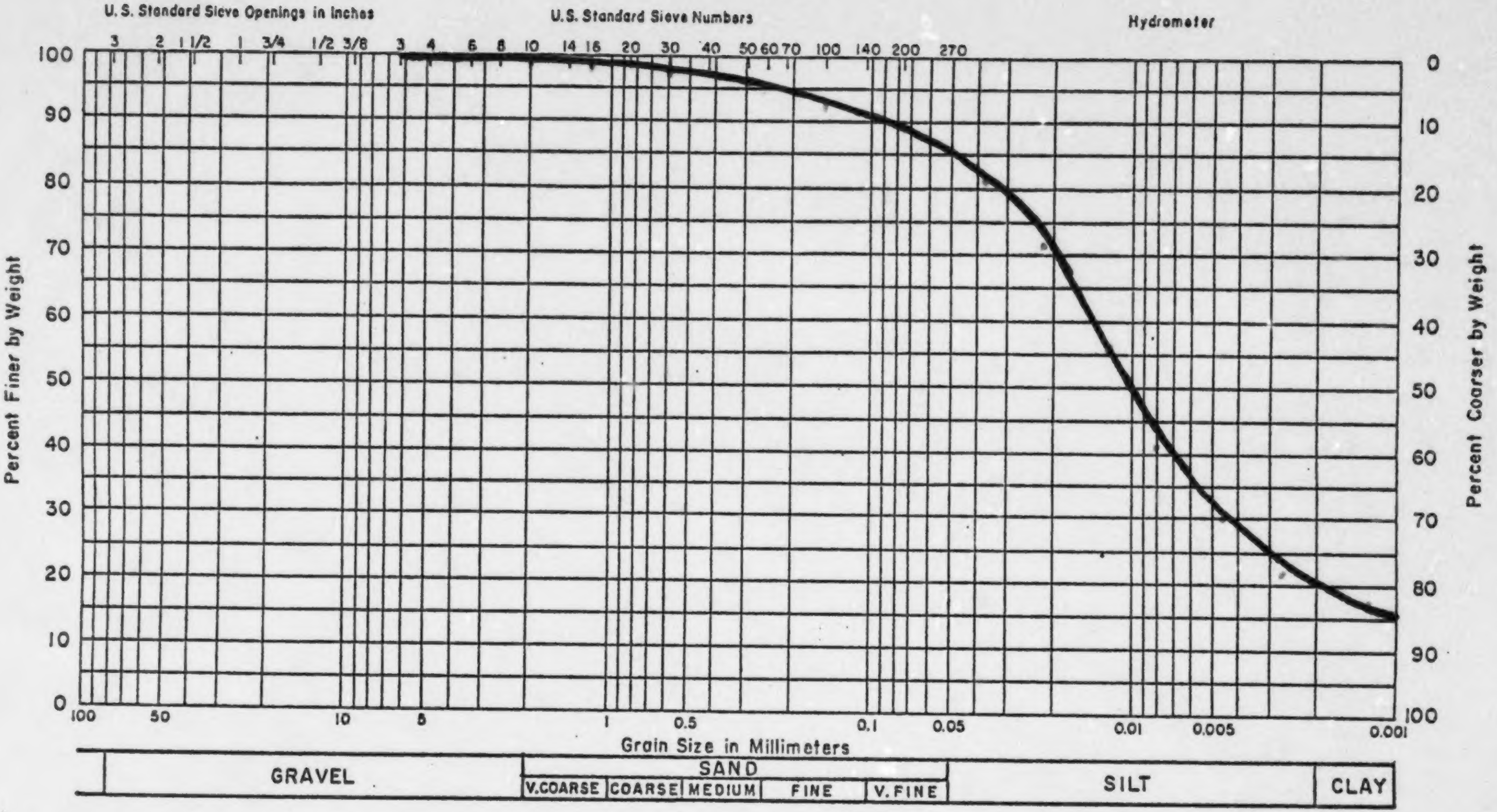
(2) ANALYSIS ON COMPOSITE ONLY.



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
884	Frankfort	13	69	18	Silt Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

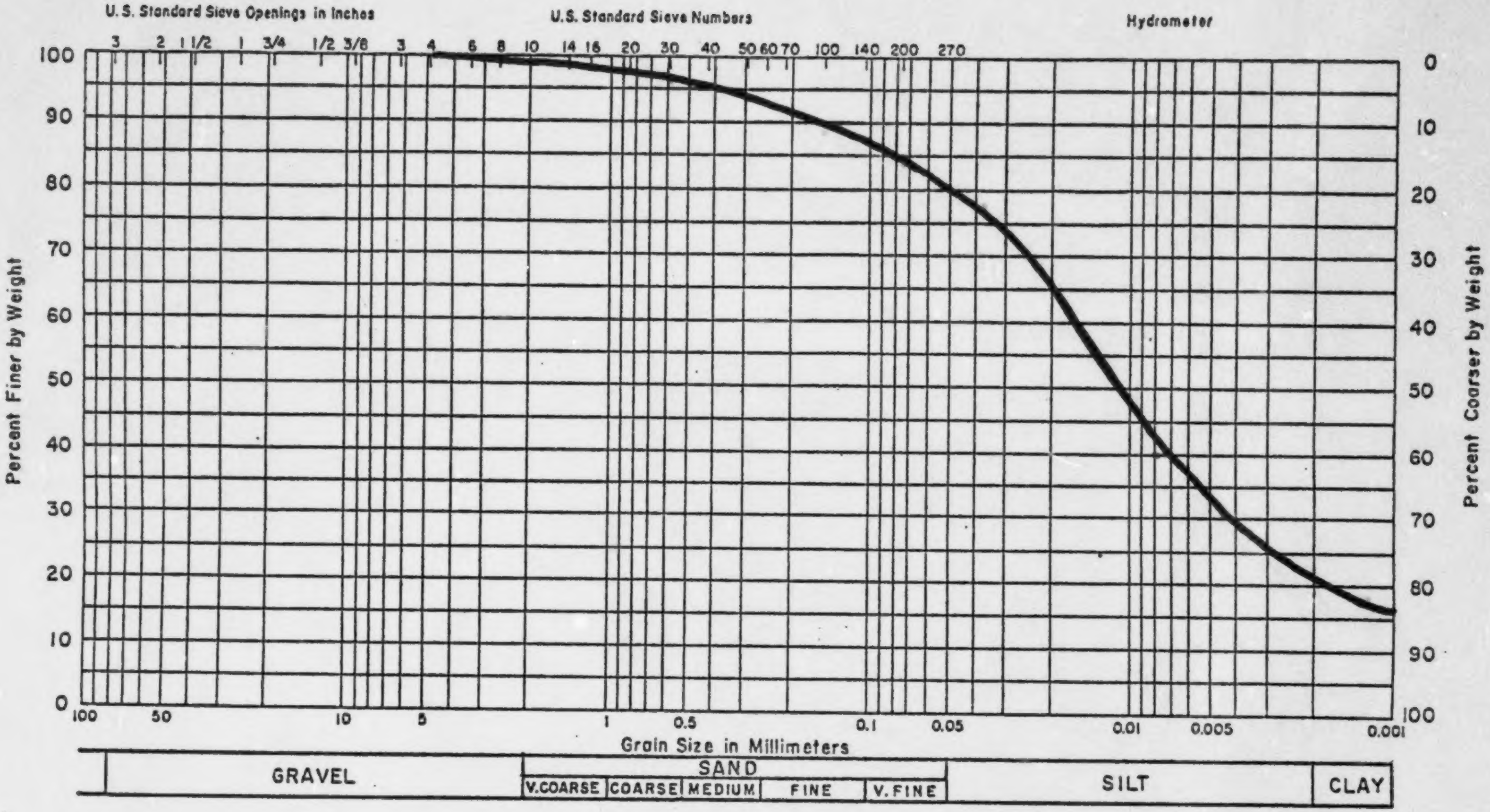
Figure 74 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
890	Frankfort	13	68	19	Silt Loam
	Treated				
	15-40 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

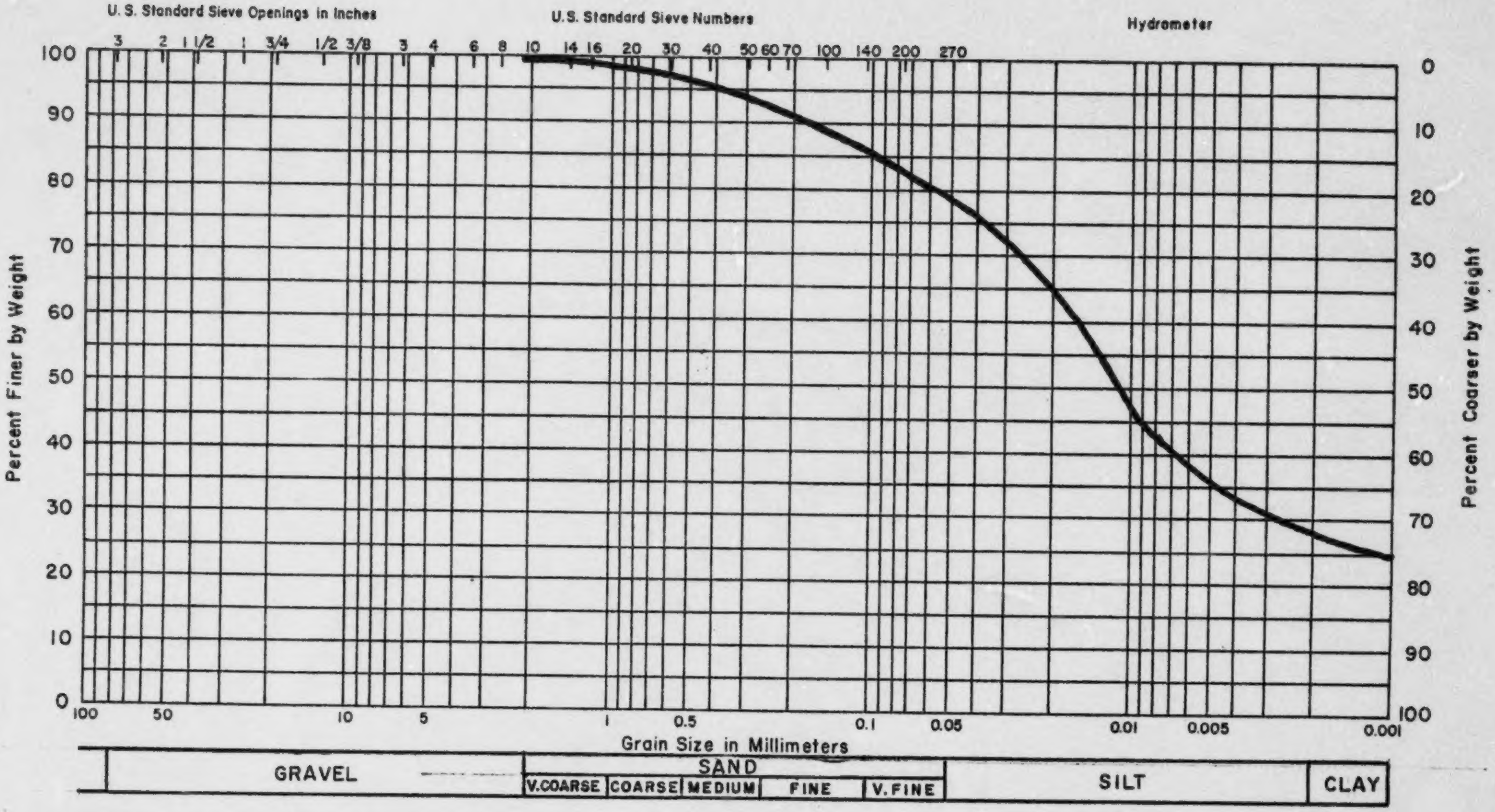
Figure 75 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
896	Frankfort	18	61	21	Silt Loam
	Treated				
	40-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

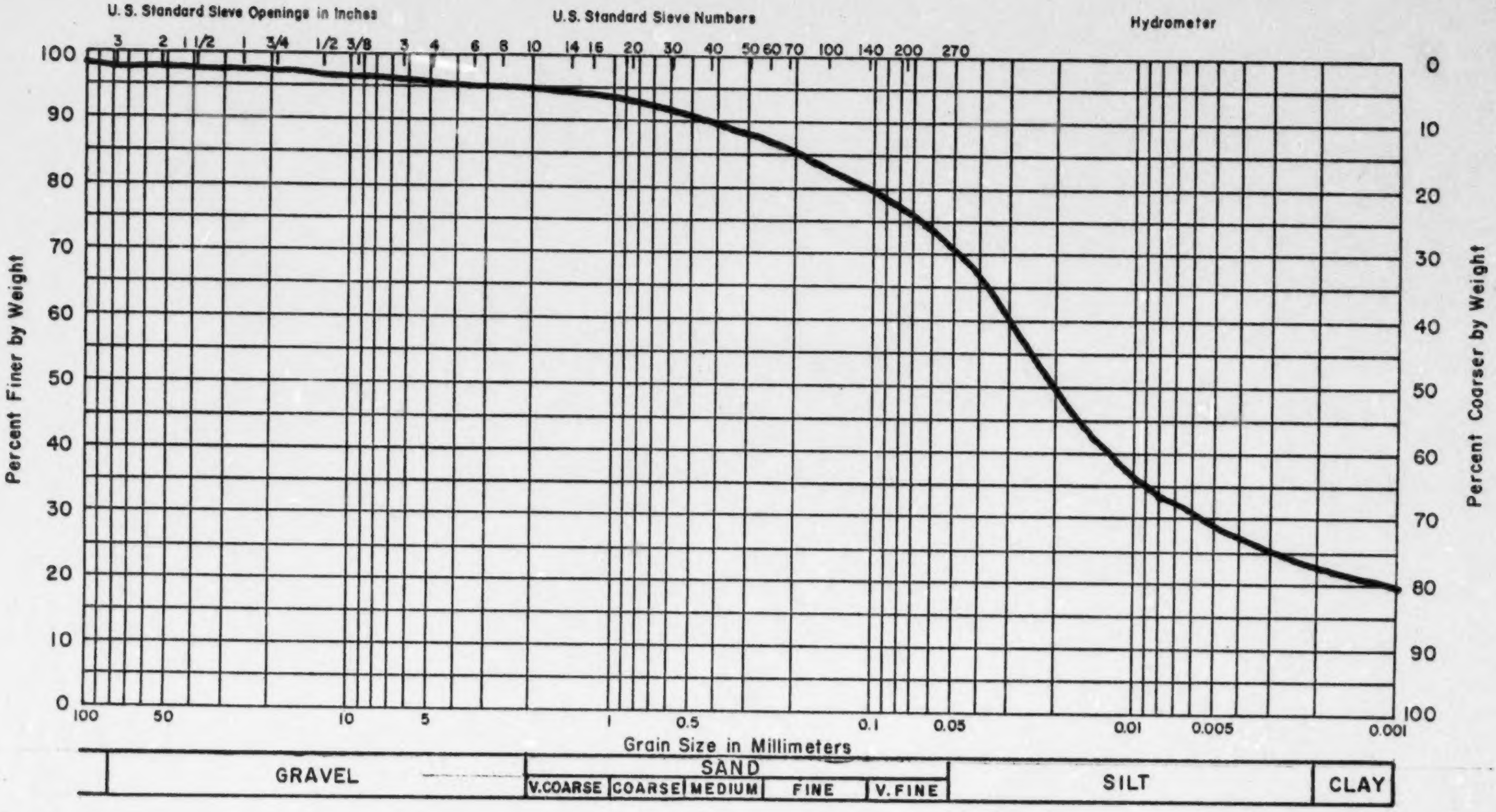
Figure 76 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
902	Frankfort	20	52	28	Silty Clay Loam/Clay Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

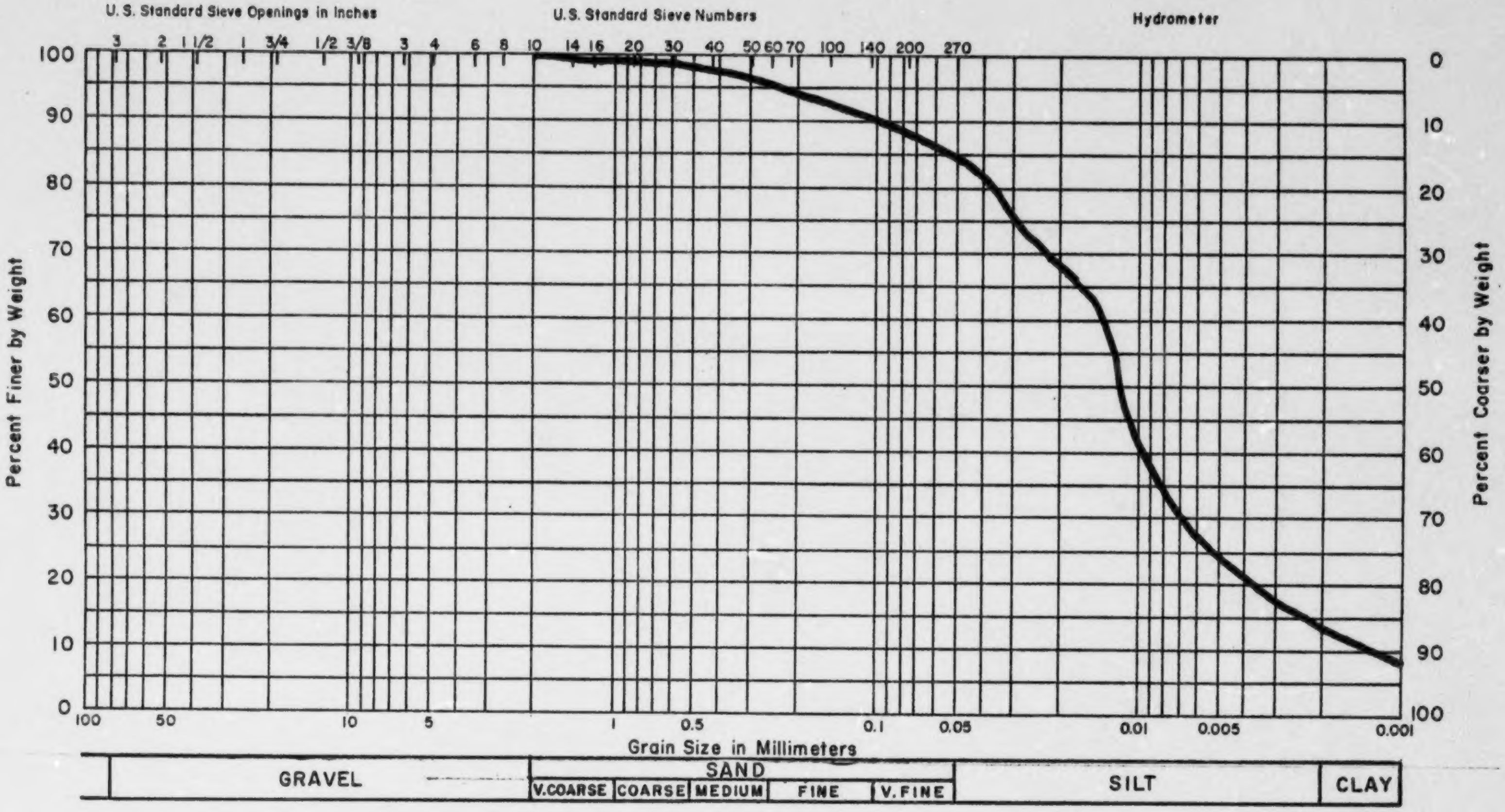
Figure 77-c Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
908	Frankfort	24	54	22	Silt Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

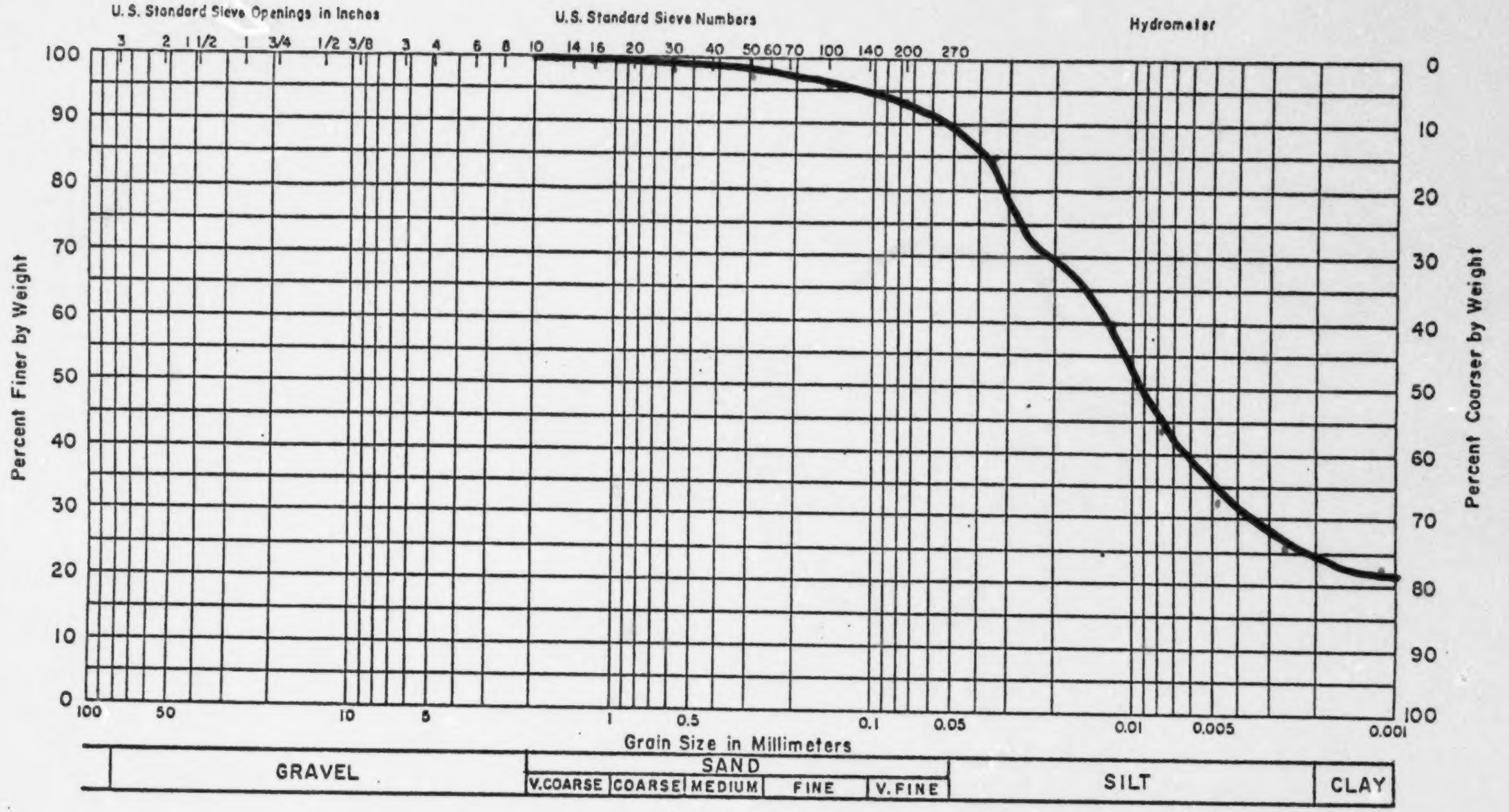
Figure 78 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
854	Frankfort	15	70	15	Silt Loam
	Control				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

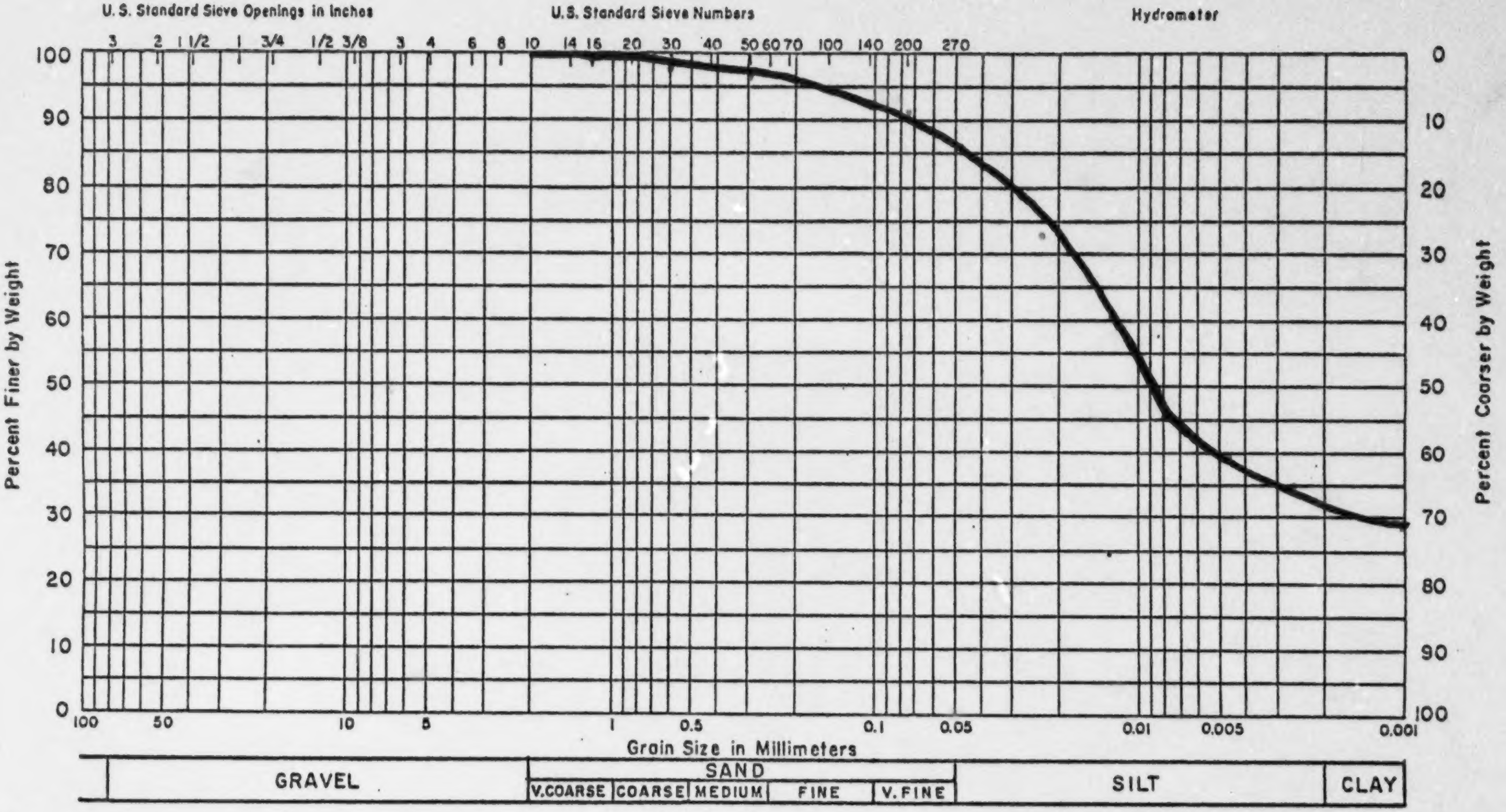
Figure 79 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
860	Frankfort Control 15-40 cm	11	65	24	Silt Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

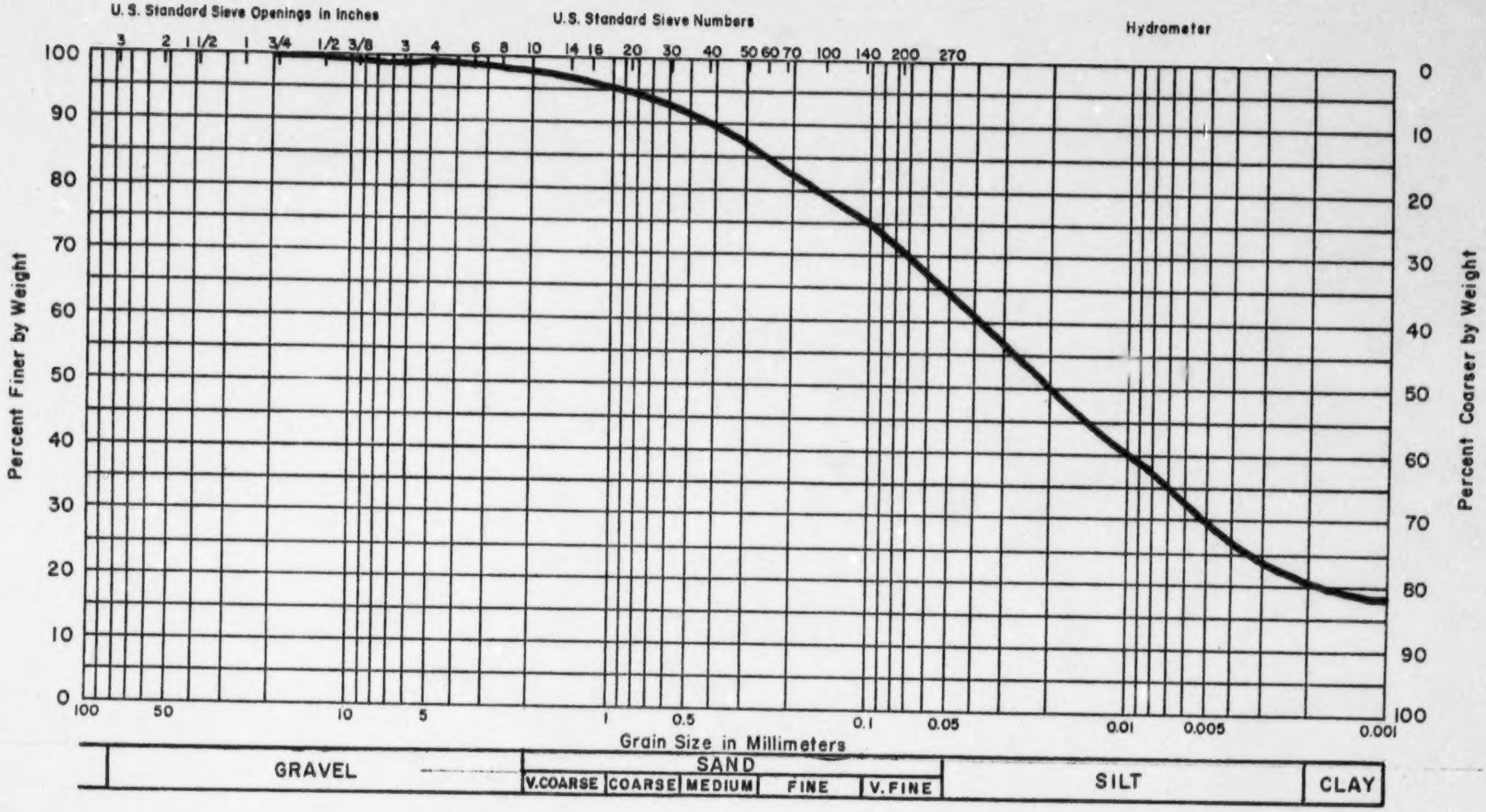
Figure 80 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
866	Frankfort	8	60	32	Silty Clay Loam
	Control				
	40-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

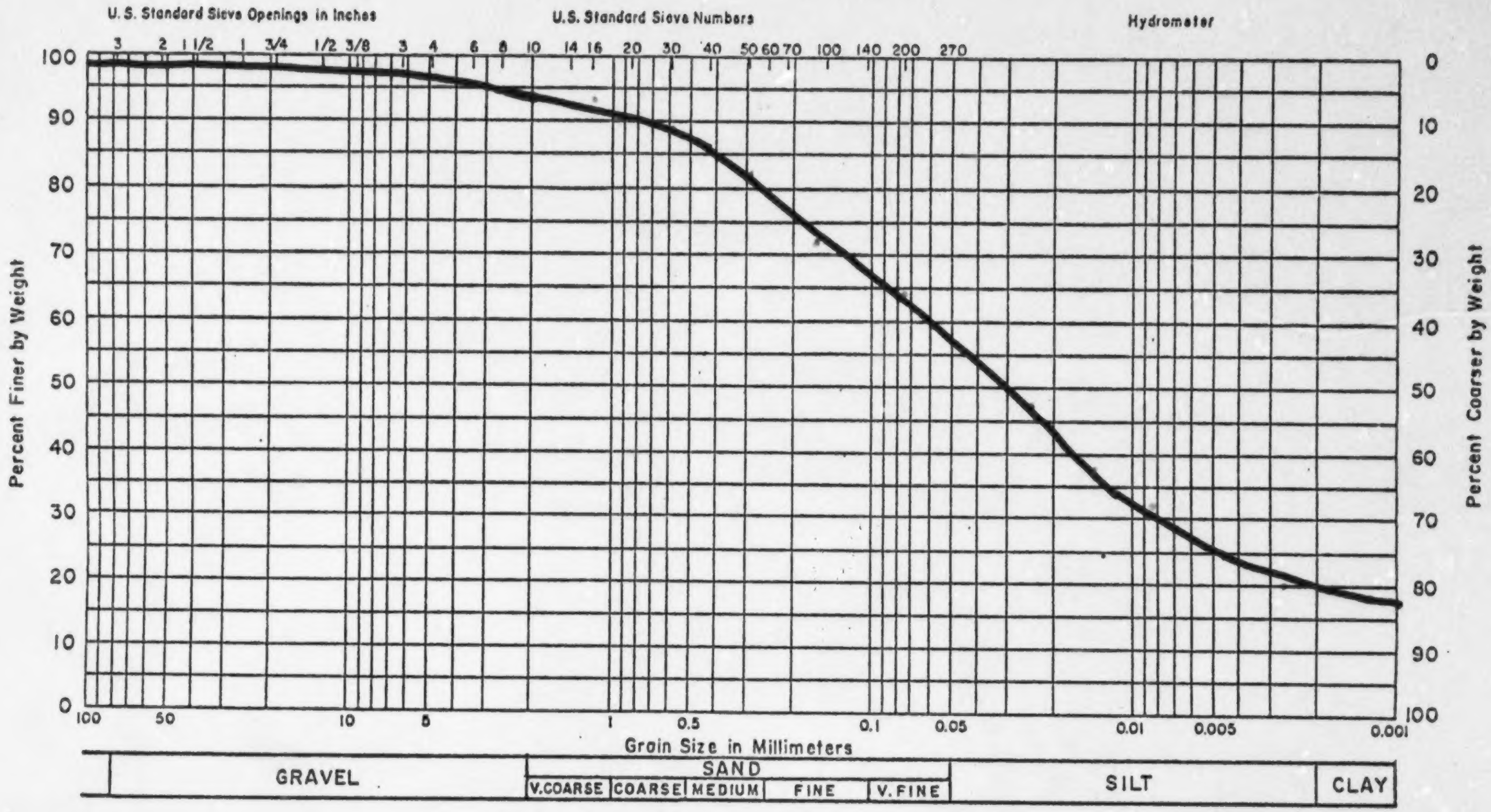
Figure 81 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
872	Frankfort	34	44	22	Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 82 Frankfort, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
878	Frankfort	39	42	19	Loam
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 83 Frankfort, IN, Particle Size Analysis

TABLE 105

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

FRANKFORT, INDIANA

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . μg/kg	. . . .	
Soil			
Surface Composites	0.5	<0.007[1]	DDT
	0.004	<0.007	DIELDRIN
	<0.75	<0.75	PCB 1221
	<0.5	<0.5	PCB 1248
Plant			
Composites	<0.125	<0.25	DDT
	3[2]	3[2]	DIELDRIN
	<0.17	<0.17	PCB 1221
	<0.11	<0.11	PCB 1248
Composites	<0.01	<0.01	DDT
	<0.02	<0.02	DIELDRIN
	<1	<1	PCB 1221
	<1	<1	PCB 1248
	(5/24/76)	(8/24/76)	
Stabilized Sludge	6.6	<0.2	DDT
	6.6	<1.35	DIELDRIN
	1382	<13.5	PCB 1221
	<1.0	<1.0	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

[2] Plant matter interference.

TABLE 106
PARASITES IN SLUDGES, SOILS, AND PLANTS
FRANKFORT, INDIANA

Sample Description	Results
Sludge	
Raw (5/24/76)	Hookworm ova, *Ascaris lumbricoides* - 50 ova/gram
Raw (8/24/76)	*Toxocara canis* - 50 ova/gram
Stabilized (5/24/76)	*Ascaris lumbricoides* - 50 ova/gram
Stabilized (8/24/76)	Negative
Planted	
Treated - Stalk	Negative
Control - Stalk	Negative
Soils - Treated Composites	
Surface	Negative
15-40 cm	Negative
40-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
15-40 cm	Negative
40-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 107

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
FRANKFORT, INDIANA

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 5/24	2.4×10^7	ND	+	+	-	ND	+	+	-	110	+	+	+	1.5×10^5	+	+	+
Raw 8/24	1.4×10^9	ND	+	-	-	ND	+	-	-	ND	+	-	-	4.8×10^8	+	+	+
Stab 5/24	5.24×10^8	ND	+	+	-	ND	+	+	-	19×10^5	+	+	+	1.9×10^6	+	+	+
Stab 8/24	3.42×10^{10}	ND	+	-	-	ND	+	-	-	160	+	+	+	9.6×10^8	+	+	+
Plants																	
Treated	1.84×10^9	ND	+	+	-	ND	+	+	-	13	+	+	+	7.7×10^3	+	+	+
Control	4.69×10^8	ND	+	+	-	ND	+	+	-	ND	+	-	-	7.5×10^3	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

343

VII-13

TABLE 107 (Continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites	(10^6)													(10^3)			
Surface	7.50	ND	+	+	-	ND	+	+	-	ND	+	-	-	1.2	+	+	+
15-40 cm	5.39	ND	+	+	-	ND	+	+	-	17	+	+	+	.13	+	+	+
40-61 cm	2.35	ND	+	+	-	ND	+	+	-	ND	+	-	+	.25	+	+	+
61-91 cm	2.09	ND	+	+	-	ND	+	+	-	ND	+	-	-	.14	+	+	+
91-122 cm	3.41	ND	+	+	-	ND	+	+	-	85	+	+	+	.24	+	+	+
Soils - Control Composites																	
Surface	8.91	ND	+	+	-	ND	+	+	-	ND	+	-	-	2.6	+	+	+
15-40 cm	5.11	ND	+	+	-	ND	+	+	-	ND	+	-	-	.13	+	+	+
40-61 cm	2.73	ND	+	+	-	ND	+	+	-	ND	+	-	-	.17	+	+	+
61-91 cm	3.33	ND	+	+	-	ND	+	+	-	ND	+	-	-	.53	+	+	+
91-122 cm	1.52	ND	+	+	-	ND	+	+	-	ND	+	-	-	.26	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

CHAPTER VIII

KENDALLVILLE, INDIANA

SITE DESCRIPTION

Location

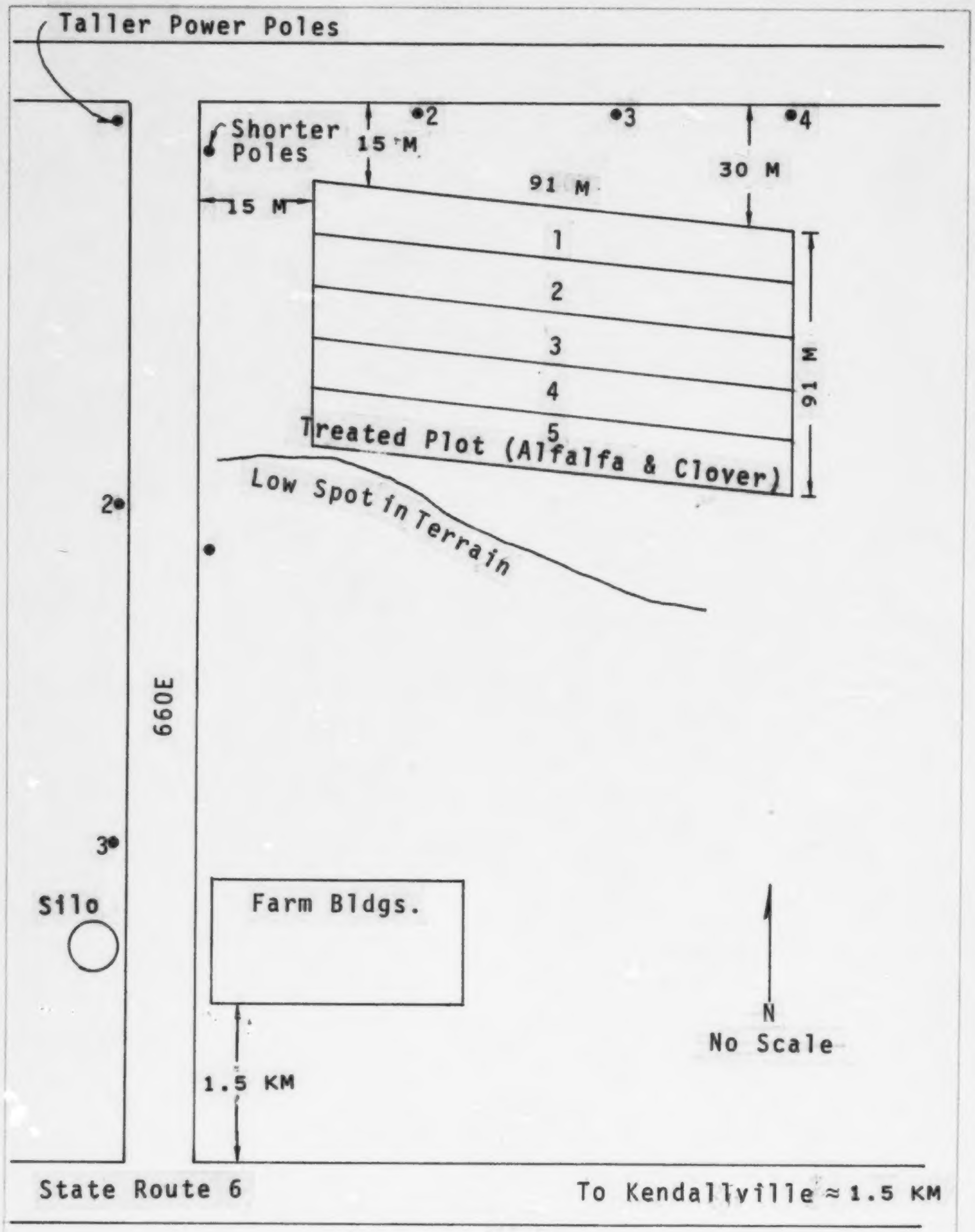
The study site is located on a 68.9 ha (170 acre) farm about 3 km (2 mi) northwest of Kendallville in northeastern Indiana, approximately 190 km (120 mi) north of Indianapolis and 160 km (100 mi) east of Chicago, Illinois. The Kendallville sewage treatment plant (STP) is located approximately 3 km (2 mi) southeast of the study site. The control plot is located on a 32.4 ha (80 acre) farm about 5 km (3 mi) east of the treated plot.

Physical Conditions

Kendallville and the neighboring towns are basically small farming and dairy communities. Crops typically grown in the area are corn, soybeans, oats, and various other feed crops. The surrounding area is characterized by rolling terrain with slopes ranging from 2 to 9 percent. Both the treated and control plots are located on similar terrain.

The treated field (see Figure 84) on which the sampled plot is located is 8.9 ha (22 acres) in size. It is one of several other fields totaling approximately 41 ha (100 acres) that have received sludge from the Kendallville STP since about 1963. The sampled plot, in the northwest corner of the field, is in the shape of a parallelogram measuring approximately 300 ft (91 m) on each side. The plot slopes gently from

345



Taller Power Poles
Shorter Poles
15 M
2
3
4
30 M
91 M
15 M
1
2
3
4
5
91 M
Treated Plot (Alfalfa & Clover)
Low Spot in Terrain
2
660E
3
Silo
Farm Bldgs.
N
No Scale
1.5 KM
State Route 6
To Kendallville ≈ 1.5 KM

Figure 84

Kendallville, Indiana · Treated Field

346

northeast to southwest. This area was estimated by the farmer to have had the most consistent applications of sludge throughout the years.

At the time of sampling (May 27, 1976), the treated field was planted in a mixture of alfalfa (Medicago sativa), orchard grass, and clover, of which alfalfa, the dominant plant, was sampled. Some areas of the field had stands of alfalfa ranging in height from 31 to 41 cm (12 to 16 in) while other areas were visibly less productive; some were even barren. The latter condition was caused by large dried crusts of sludge up to 2.5 cm (1 in) thick. Noticeable alfalfa weevil damage was observed throughout the field.

Groundwater is estimated to be at a depth of 31 m (100 ft) in the vicinity of the treated plot.

The farm on which the control plot is located is on steeper sloped ground that the treated farm, but the plot sampled is on a very gently sloped plateau measuring about 91 m (300 ft) square (see Figure 85). Alfalfa and other grasses on the control plot were the same mixture as on the treated plot. Alfalfa was estimated to comprise about 70 percent of the crop with an average height between 46 and 61 cm (18 and 24 in). Alfalfa weevil damage was also apparent in this field.

Farming Practices

The field on which the treated plot is located is in a current rotation of one year corn, one year soybeans, one year oats, and two years alfalfa (one year pasture and one year hay).

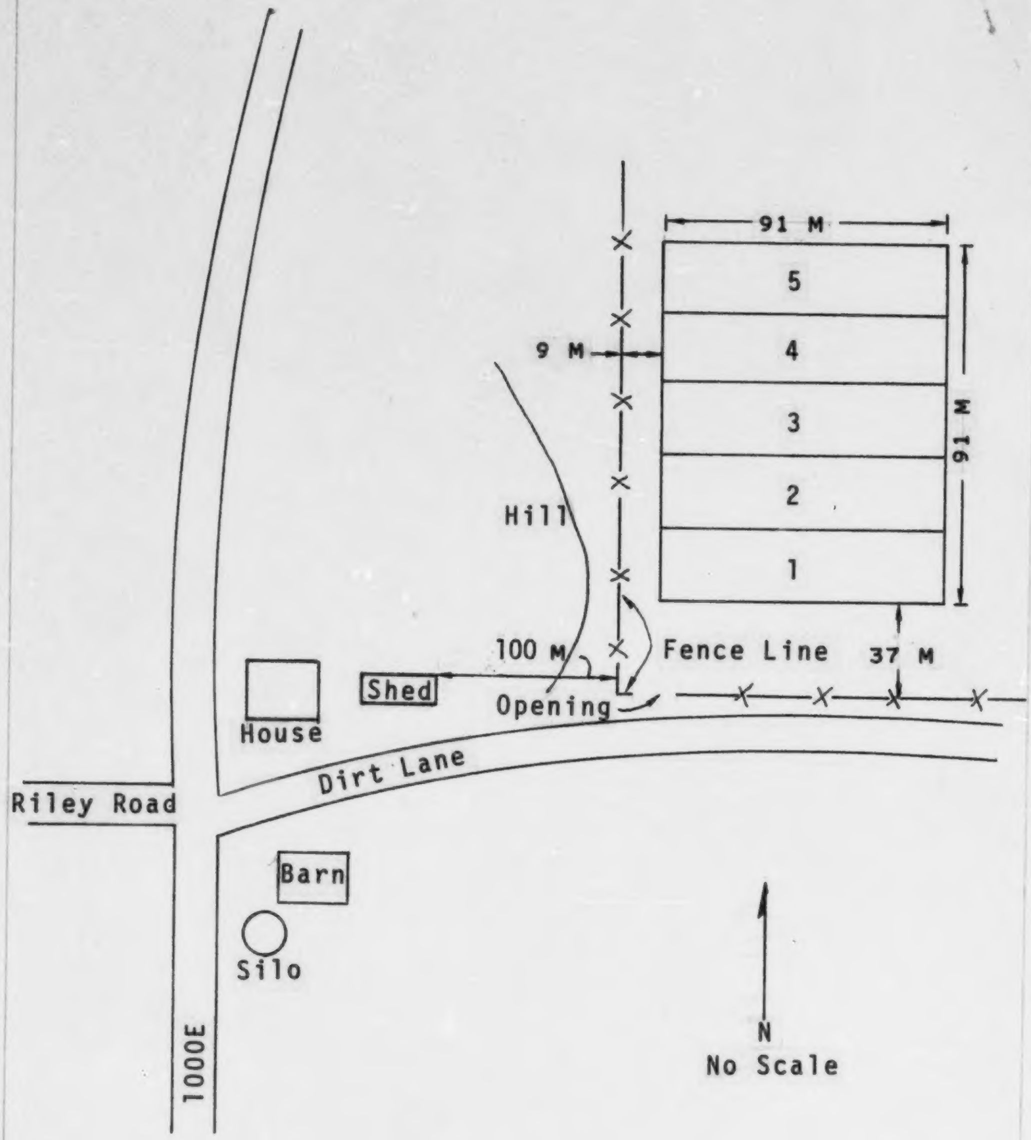

91 M
5
4
3
2
1
9 M
91 M
Hill
100 M
Fence Line
37 M
Shed
Opening
House
Dirt Lane
Riley Road
Barn
Silo
1000E
N
No Scale

Figure 85

Kendallville, Indiana - Control Field

The 1976 crop was to be cut for hay shortly after samples were obtained for this study. Yields were not available for any of the crops for any year.

The field is typically cultivated to a depth of 20 to 25 cm (8 to 10 in) with a mold board plow, and 8-16-16 fertilizer applied at 40 to 50 kg/ha (300 to 400 lbs/acre). No pesticides or herbicides are used during the two-year alfalfa cycle. When the field is planted to corn, however, Atrazine and Lasso at 2.2 kg/ha (2 lbs/acre) are applied. The treated plot has never been limed. The crops grown on the treated plot are used for non-dairy cattle feed. No adverse effects to livestock have been reported by the resident farmer.

Since 1963, all sludge from the Kendallville STP has gone to the study site. Spreading, however, has been inconsistent, especially during periods of inclement weather when the truck drivers have historically dumped sludge in the most easily accessible areas. This has resulted in visible ponding and sludge accumulations ranging from several inches to several feet. This was evident in lower areas of other adjacent sludge treated fields. Based on STP records and assuming that 41 ha (100 acres) have been used for spreading, application rates over the years have been estimated and are shown in Table 108.

Approximately half of the control site farm property is permanent pasture with the remaining area on a rotation of four to five years alfalfa, one year corn, one year soy, and one year oats. At the time of sampling, the control plot was

TABLE 108

KENDALLVILLE, INDIANA - SLUDGE APPLICATION RATES[1]

Year	Dry Metric Tons/ha
1967	2.5
1968	2.9
1969	2.9
1970	4.7
1971	4.9
1972	8.1
1973	15.9
1974	19.3
1975	19.7

[1] Based on 4.0 percent sludge solids (average analytical data) ; averages were estimated from available hauling logs.

planted to the same variety of alfalfa (Funks G) as was the treated plot.

Field preparation is similar to that for the treated field, but potash at 280 kg/ha (250 lbs/acre) and lime (when needed) at 2.2 kg/ha (2 tons/acre) are applied. Pesticide Sevin is used to control alfalfa weevil. When corn is planted, Atrazine and Lasso are applied at an unknown application rate.

The alfalfa crop on the control plot appeared to be more uniform and considerably more abundant than on the treated plot. There were some areas on both plots where growth was 25 to 30 cm (10 to 12 in), but the treated plot had many barren spots due to the accumulation of dried sludge. While no yield data were available, it was estimated that yields from the control plot would be significantly higher than those from the treated plot.

CLIMATE

Kendallville's climate is moderated by the Great Lakes and does not differ significantly from other mid-western cities of the same general latitude. Daily 24-hour temperature ranges of 11°C (20°F) are not uncommon. The seasonal range is from a winter minimum of about 11°C (20°F) to a summer maximum near 29°C (85°F). The average date of the last freeze in the spring is April 26, and the first freeze in the fall is ordinarily October 17, making the average freeze-free period 173 days. The length of the growing season is favorable for the maturing of all crops and vegetables normally grown in the midwest.

Precipitation, normally averaging about 91 cm (36 in) a year, is well distributed, with monthly amounts ranging from near 5 cm (2 in) in February to near 10 cm (4 in) in May, June, and July. Damaging hailstorms occur about twice a year. Snow usually covers the ground for about 30 days during the winter months, but heavy snowstorms are infrequent. Only twice since 1911 has a single 24-hour fall exceeded 30 cm (1 ft) in depth. Additional meteorological data are presented in Table 109.

SOIL DESCRIPTION

Regional Area

The treated and control plots are characterized by soils of the Rawson-Morley-Miami complex. In the opinion of the resident Soil Conservation Service scientist, the treated plot consists mainly of the Morley series (estimated at 90 percent), while the control plot is exclusively of the Morley series. The Miami series was not observed at either plot.

Morley soils are on till plains of Wisconsin age. Slopes are commonly between 3 and 12 percent, but may range from 1 to 25 percent. These soils are formed in calcareous clay loam to silty clay loam glacial till that, in some places, has a mantle of less than 46 cm (18 in) of loess or glacial drift. Morley soils typically have light-colored silty Ap and A2 horizons; brown, fine-textured B horizons, free of mottling in the upper part; and C horizons of calcareous loamy glacial till.

A typical profile of Morley silt loam as mapped by the Soil Conservation Service follows:

TABLE 109

KENDALLVILLE, INDIANA

Meteorological Data For The Current Year

Station: Fort Wayne, Indiana — Standard time used: EASTERN — Latitude: 41° 00' N — Longitude: 85° 12' W — Elevation (ground): 791 feet — Year: 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity, pct.				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Averages			Extremes						Water equivalent			Snow, Ice pellets							Resultant			Fastest mile					Sunrise to sunset							Temperature °F Maximum		Temperature °F Minimum		Elev.
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	Hour 01 (Local time)	Hour 07 (Local time)	Hour 13 (Local time)	Hour 19 (Local time)	Direction	Speed m.p.h.	Average speed m.p.h.	Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	828 feet m.s.l.
JAN	35.9	23.6	29.8	60	10	6	20	1084	0	2.41	0.63	7-8	5.8	2.0	18	79	82	72	76	24	7.9	13.5	50	SW	10	47	8.0	4	5	22	17	1	1	0	0	10	28	0	986.8
FEB	33.6	21.9	27.8	48	21	-13	10	1035	0	2.05	1.01	22-23	5.2	1.8	8-9	77	78	73	74	25	3.4	12.9	47	W	25	41	8.4	2	5	21	14	1	0	5	0	10	26	2	986.1
MAR	41.2	25.0	33.1	63	21	3	15	981	0	2.03	0.58	7	9.2	4.5	14	77	81	66	67	30	1.9	12.8	37	W	30	58	7.8	2	7	22	12	3	3	3	0	7	26	0	985.1
APR	53.5	34.3	43.9	74	29	21	12	628	2	3.39	1.10	23-24	0.9	0.9	3	75	78	58	59	02	2.0	12.3	42	SW	18	59	6.9	6	5	19	11	0	5	3	0	0	18	0	987.8
MAY	73.9	51.9	62.9	91	20	41	2	135	76	2.77	1.56	21-22	0.0	0.0		80	85	56	58	22	1.1	9.0	45	W	25	75	6.6	5	12	14	13	0	6	1	1	0	0	0	984.8
JUN	79.4	59.7	69.6	90	29	42	8	48	192	4.40	1.40	14-15	0.0	0.0		88	89	67	69	22	3.4	9.6	34	SW	17	74	6.2	8	7	15	13	0	9	1	2	0	0	0	985.8
JUL	85.1	60.6	72.9	93	31	49	14	8	256	0.79	0.55	19	0.0	0.0		80	84	47	51	26	3.1	7.6	28	NW	12	69	4.5	12	14	5	4	0	3	0	6	0	0	0	986.5
AUG	82.1	63.9	73.0	91	1	47	8	4	260	7.69	1.92	2-3	0.0	0.0		88	91	66	71	22	2.3	8.4	26	E	22	74	7.3	3	9	19	13	0	11	2	1	0	0	0	988.2
SEP	69.5	51.0	60.3	86	3	36	14	173	37	3.48	1.71	11-12	0.0	0.0		86	89	63	69	28	1.9	8.7	37	N	5	57	6.3	8	7	15	10	0	2	2	0	0	0	0	989.2
OCT	65.2	42.6	53.9	84	13	30	30	346	9	1.70	0.72	18-19	0.0	0.0		78	84	54	63	23	2.7	9.7	32	NW	25	69	5.1	12	9	10	9	0	0	1	0	0	3	0	989.5
NOV	55.5	37.7	46.6	78	6	23	23	546	1	3.17	0.76	6-7	6.0	4.4	26-27	79	80	65	73	22	7.3	11.4	39	W	10	49	6.6	8	8	14	13	3	0	0	0	2	12	0	987.8
DEC	37.6	25.1	31.4	66	14	9	18	1036	0	2.85	1.36	14-15	10.0	4.9	25-26	78	78	72	76	27	2.1	11.4	29	W	1	35	8.0	2	9	20	13	4	2	1	0	10	24	0	989.5
YEAR	59.4	41.4	50.4	93	JUL 31	-13	FEB 10	6024	833	36.73	1.92	AUG 2-3	37.1	4.9	DEC 25-26	80	83	63	67	24	2.7	10.6	50	SW	JAN 10	63	6.8	72	97	196	142	12	42	19	10	39	137	2	987.3

TABLE 109 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F Normal Daily maximum	Daily minimum	Monthly	Extremes Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling
(a)				15		15			
J	32.6	17.9	25.3	61	1967	-19	1972	1231	0
F	35.5	19.7	27.6	62	1972	-18	1963	1047	0
M	45.1	27.9	36.5	79	1963	-10	1967	884	0
A	59.5	39.0	49.3	87	1962	15	1972	471	0
M	70.2	48.9	59.6	91	1975	27	1966	218	48
J	80.1	58.8	69.5	97	1971	39	1972	23	158
J	83.6	62.4	73.0	98	1974	44	1967	0	251
A	82.2	60.4	71.3	101	1962	38	1965	12	207
S	75.9	53.0	64.5	94	1964	31	1974	90	75
O	64.6	42.5	53.6	89	1963	23	1974	363	9
N	48.3	32.0	40.2	78	1975	10	1964	744	0
D	35.7	21.4	28.6	67	1970	-10	1963	1128	0
YR	59.4	40.3	49.9	101	AUG 1962	-19	JAN 1972	6209	748

Month	Precipitation in inches Water equivalent Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)		29		29		29		29		29	
J	2.49	9.72	1950	0.39	1966	2.64	1950	11.7	1957	6.5	1964
F	2.05	4.43	1950	0.41	1969	1.92	1959	13.1	1960	7.7	1952
M	2.90	5.29	1955	0.81	1958	2.15	1953	19.5	1964	13.6	1964
A	3.56	7.11	1957	1.28	1962	2.65	1963	11.7	1961	6.4	1957
M	3.85	6.85	1952	1.21	1950	3.24	1968	T	1966	T	1966
J	3.91	8.29	1958	1.15	1966	3.78	1959	0.0		0.0	
J	3.89	6.34	1951	0.41	1974	3.47	1955	0.0		0.0	
A	2.90	7.69	1975	0.42	1969	4.05	1957	0.0		0.0	
S	2.56	6.75	1972	0.70	1973	4.60	1950	0.0		0.0	
O	2.84	9.26	1954	0.14	1964	2.96	1947	1.4	1974	1.4	1974
N	2.65	5.28	1950	0.90	1949	2.06	1969	14.1	1950	7.0	1950
D	2.20	5.45	1967	0.42	1962	2.14	1966	20.3	1973	11.1	1973
YR	35.80	9.72	JAN 1950	0.14	OCT 1964	4.60	SEP 1950	20.3	DEC 1973	13.6	MAR 1964

Month	Relative humidity pct. Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind Mean speed m.p.h.	Prevailing direction	Fastest mile Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset
(a)	14	14	14	14	29	14	29	29		29	29
J	78	80	71	75	11.5	W	59	SW	1949	42	7.6
F	76	78	67	70	11.6	W	61	W	1967	47	7.2
M	77	80	66	68	12.2	W	65	S	1948	51	7.4
A	75	78	58	59	12.0	SW	63	W	1962	59	7.0
M	76	79	56	57	10.5	SW	57	S	1960	65	6.4
J	77	81	56	57	9.2	SW	65	SE	1948	70	6.2
J	80	83	54	57	8.2	SW	61	NW	1954	73	5.8
A	82	86	57	60	7.8	SW	55	N	1965	72	5.5
S	82	87	58	64	8.6	SW	52	W	1960	65	5.7
O	79	84	57	65	9.2	SW	40	W	1958	62	5.6
N	80	83	68	75	11.2	W	57	SW	1957	41	7.3
D	82	83	75	79	11.3	W	52	SW	1953	37	7.7
YR	79	82	62	66	10.3	SW	65	SE	JUN 1948	59	6.6

Month	Mean number of days Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max. (b) 90° and above	32° and below	Min. 32° and below	0° and below	Average station pressure mb. Elev. 828 feet m.s.l.
(a)	29	29	29	29	29	29	29	14	14	14	14	3
J	4	7	20	12	2	*	3	0	16	28	5	988.2
F	5	6	17	11	2	1	2	0	12	26	3	987.2
M	4	8	19	14	2	3	2	0	4	22	*	984.9
A	5	8	17	14	*	5	1	0	0	10	0	985.4
M	6	10	15	12	0	6	1	*	0	1	0	983.4
J	6	12	12	11	0	8	1	4	0	0	0	984.5
J	8	12	11	10	0	7	1	5	0	0	0	986.7
A	9	12	10	8	0	6	2	4	0	0	0	988.2
S	9	9	12	9	0	4	2	1	0	*	0	988.8
O	11	8	12	8	*	2	2	0	0	5	0	990.1
N	5	7	18	11	1	1	2	0	2	15	0	987.6
D	4	6	21	13	2	*	3	0	12	25	2	987.8
YR	76	105	184	132	10	41	23	14	46	133	10	986.9

- 0 to 10.2 cm (0 to 4 in) - Very dark gray silt loam; moderate fine granular structure; friable; slightly acidic.
- 10.2 to 22.9 cm (4 to 9 in) - Grayish-brown silt loam; weak fine platy structure; friable; strongly acidic.
- 22.9 to 35.6 cm (9 to 14 in) - Dark brown to brown heavy silty clay loam containing some sand; moderate fine subangular blocky structure; firm; very thin, continuous; strongly acidic.
- 35.6 to 48.3 cm (14 to 19 in) - Brown heavy silty clay loam; moderate fine prismatic structure breaking to moderate fine subangular blocky structure; very firm; thin, discontinuous; few pebbles; strongly acidic.
- 48.3 to 71.1 cm (19 to 28 in) - Brown silty clay, common fine faint yellowish brown mottles; moderate medium prismatic structure breaking to moderate fine to medium subangular blocky structure; very firm; thick, continuous, very dark grayish-brown clay films; few pebbles; slightly acidic.
- 71.1 to 86.4 cm (28 to 34 in) - Brown silty clay loam; many, fine, faint, yellowish-brown mottles; moderate medium prismatic breaking structure to moderate medium subangular blocky structure; firm; discontinuous, brown clay films; few pebbles; mildly to moderately alkaline; clear smooth boundary.
- 86.4 to 107 cm (34 to 42 in) - Brown silty clay loam; many, medium, distinct, gray mottles and many, medium,

355

faint, yellowish-brown mottles; weak medium prismatic structure breaking to moderate medium blocky structure; firm; few pebbles; calcareous; clear smooth boundary.

107 to 122 cm (42 to 48 in) - Brown silty clay loam; many, medium, distinct, gray mottles; structureless, massive; firm; calcareous glacial till.

Treated and Control Plots

The sampled surface and subsurface soils were found to be similar to the above profile descriptions through the first 122 cm (48 in). The presence of pebbles between the 30 cm (1 ft) and 61 cm (2 ft) levels on both plots prevented the use of a hand bucket auger. Subsurface samples were obtained with a pneumatic 5 cm (2 in) diameter core drill mounted on the back of a pick-up truck (see Sampling and Analysis for more detailed description).

Moisture, pH, and other analytical data for soils of the treated and control plots are presented in Table 110.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The Kendallville Wastewater Treatment Plant (STP), providing secondary treatment of all wastewater, serves an actual population of 9,200 and an equivalent (12-month average) population of 22,700. The plant was constructed in 1958 and expanded in 1972 to serve the growing population. Expansion consisted of the addition of four primary settling tanks, two trickling filters, and one final clarifier.

356

TABLE 110

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

KENDALLVILLE, INDIANA

PLOT/ DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N[2]	PH[1]	CEC
			SAND	SILT	CLAY					
	PERCENT						µG/G			MEQ/ 100GMS
TREATED										
SURFACE	11.8	1.63	31	40	29	0.117	1.60	23.0	6.4	27
20-30 CM	13.2	0.75	28	40	32	0.084	0.46	19.30	7.2	20
30-61 CM	14.2	0.43	24	37	39	0.062	2.70	8.90	7.9	27
61-91 CM	14.4	0.30	26	39	35	0.048	3.90	1.20	8.2	27
91-122 CM	12.7	0.20	28	41	31	0.037	1.00	2.70	8.1	11
CONTROL										
SURFACE	12.4	1.63	40	41	19	0.162	4.30	47.0	6.6	10
20-30 CM	11.5	1.08	34	42	24	0.104	1.00	3.70	6.6	23
30-61 CM	13.1	0.47	34	36	30	0.067	1.10	1.00	7.6	16
61-91 CM	13.0	0.43	39	35	26	0.045	2.79	1.00	8.0	14
91-122 CM	12.9	0.21	39	33	28	0.035	0.60	1.80	8.1	16

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

The STP treats an average flow of 5,700 to 6,400 cu m/day (1.5 to 1.7 mgd) with three trickling filters having a design capacity of 10,100 cu m/day (2.68 mgd). The treatment process consists of grit removal, primary settling, trickling filter secondary treatment, and secondary clarification, followed by contact chlorination and discharge to Henderson Lake. Based on an average flow, primary settling detention time is approximately 4.3 hours; residence time in the secondary clarifiers averages 2.6 hours. Trickling filter surface area totals 0.150 ha (0.371 acres) of exposed rock media. Secondary treatment efficiencies are shown in Table 111.

Phosphorous is precipitated by the daily addition of about 450 l (120 gal) of 42 percent ferric chloride. The solution is added to the secondary clarifier influent.

Dubois Floculite 550 at a dilution of 1.7 kg/kl (7 lbs/500 gal) enhances coagulation in the secondary clarifiers. Actual consumption averages about 3 kg/day (7 lbs/day).

An estimated 20 to 25 percent of the total flow is from industrial sources. Industries that contribute significant amounts of influent to the STP are listed below:

Industry	Product Manufactured
Flint & Walling	Pumps
Kraft	Foods
Essex Wire	Wires of all types
Newnan Foundry	Metal products of all types
Kendallville Foundry	Metal products of all types

TABLE 111

KENDALLVILLE, INDIANA - SECONDARY EFFLUENT TREATMENT EFFICIENCIES

	Avg. Daily Flow (cu m/day)	Influent		Effluent		% Reductions	
		BOD (mg/1)	SS (mg/1)	BOD(mg/1)	SS(mg/1)	BOD	SS
May, 1975	6018	357	201	11	7.7	96.9	96.2
June	6435	342	186	26	11	92.4	94.1
July	3974	396	172	24	7	93.9	95.9
Aug.	4542	355	318	18	10	94.9	96.9
Sept.	4164	257	316	15	13	94.2	95.9
Oct.	4164	300	394	23	10	92.3	97.5
Nov.	4921	369	270	22	8	94.0	97.0
Dec.	5299	316	251	26	7.8	91.8	96.9
Jan., 1976	4921	366	208	30	17	91.8	91.8
Feb.	7192	306	270	35	38	88.6	85.9
March	7570	249	331	28	42	88.8	87.3
April	6056	254	391	23	22	90.9	94.4
Average	5438	322	276	23.4	16.1	92.5	94.2

BOD and suspended solids (SS) analyses are routinely performed in-house by Kraft and average approximately 730 and 190 mg/l, respectively. The STP does not experience seasonal fluctuations from any of the processors.

Sludge Stabilization and Storage

Sludge is returned by gravity from the secondary to the primary clarifiers where it is pumped either to an Imhoff holding tank or to an anaerobic digestion tank, the capacities of which are 878 and 428 cu m (231,880 and 112,948 gal), respectively. The anaerobic digester has a maximum retention capacity of 14 days. Excess sludge can be stored in the Imhoff for an additional 30 days. Due to the limited capacity of the anaerobic digester, sludge is sometimes pumped directly to the Imhoff, bypassing the digester. This occurs quite often during periods of inclement weather. Since the sludge trucks are loaded from the Imhoff tank, both stabilized and partially-stabilized sludges are at times mixed and landspread together.

Two drying beds, each having an area of 37.2 sq m (4,000 sq ft) are available for additional sludge storage but have not been used in several years.

A grab sample of stabilized sludge was obtained from the STP in September, 1975. The results of that analysis, comprising the only known sludge data, are shown in Table 112. The lead (Pb) level is extremely high. Since none of the industrial effluents have ever been monitored, the origin of the Pb is unknown.

TABLE 112

KENDALLVILLE, INDIANA - STABILIZED LIQUID SLUDGE ANALYSES[1]

Parameter	Concentration (µg/g)[2]
Cd	28.3
Cu	446
Ni	75.9
Pb	8176
Zn	4882
Moisture (%)	93.2

[1] Phase I stabilized sludge sample, September, 1975.

[2] Data expressed on an oven dry weight basis.

Disposal of Sewage Sludge

From records provided by the STP from 1967 through 1975, the quantities of sludge generated can be seen to be increasing (see Table 113). Specifically, the amount of sludge spread in 1973 was approximately double that of 1972. The STP superintendant, however, attributed this difference to the 1972 plant expansion which was completed at the beginning of 1973.

Assuming an average sludge solids content of 4.0 percent, average sludge generated annually (1973-75) is 739 dry m tons (815 dry tons). All liquid sludge generated at the STP has been spread on the 40.5 ha (100 acres) of which the treated plot is a part.

The Kendallville STP contracts with an outside trucking company for sludge hauling. The truck is equipped with a 9.5 cu m (2,500 gal) tank, fitted with a 15 cm (6 in) diameter discharge pipe. Typically, the truck is driven across the field with the valve open, allowing the sludge to pour onto the ground. One tank full covers an area approximately 1 to 1.5 m (3 to 5 ft) in width and 300 m (1,000 ft) in length.

As mentioned in Farming Practices, however, some areas of the various fields have served as dumping grounds for sludge, especially during periods of wet weather.

Prior to 1967, sludge was hauled with STP equipment. Frequent and costly mechanical breakdowns, however, compelled the city to contract with a private hauler. The city presently pays the contractor $10 per load for hauling the sludge to the

TABLE 113

KENDALLVILLE, INDIANA - SLUDGE GENERATION

Year	Dry Metric Tons[1]
1967	108
1968	130
1969	129
1970	215
1971	223
1972	358
1973	713
1974	857
1975	875

---

[1] Solids at 4.0 percent (averaged analytical data).

farmer's fields. The contractor in turn pays the farmer $1 per load to dump on farm property.

Interviews with the farmer and STP personnel indicate that the only problem associated with sludge disposal has been a complaint in early 1976 from a neighbor regarding the odor emanating from newly spread sludge. The problem was not severe, however, and has not affected continued disposal at the study site.

Photographs 32 through 36 show, respectively, sludge swath on the treated plot, the treated plot, the control plot, the sludge spreading truck, and a view of the alfalfa sampled from the treated plot.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

Personnel from the Kendallville News Sun, the Noble County Board of Health, and the Kendallville City Health Department were interviewed to assess their awareness of the sludge spreading practices. The Managing Editor of the News Sun stated that in the five previous years, no articles had appeared relative to sludge spreading.

The Noble County Sanitarian related that in early 1976, a neighbor living adjacent to the treated field lodged a complaint regarding possible effects of sludge "run-off" contaminating a creek or river. Upon examination, however, the Sanitarian determined that the complaint had no public health significance. When asked how he viewed the sludge spreading program, he answered that for all practical purposes, he saw

Photograph . 32

Sludge on Treated Field

Photograph 33

Treated Plot

365

Photograph 34

Control Plot

Photograph 35

Sludge Spreading Truck

Photograph 36

Alfalfa Treated Plot

no appreciable difference between the use of sewage solids or animal wastes as a fertilizer source.

The Kendallville Health Officer was interviewed regarding any potential health problems associated with sludge spreading. He was not aware of the local sludge utilization program.

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

There are currently no Indiana state regulations governing application of sludge to agricultural land. The STP superintendent stated that no permits are required for either disposal or transportation of sludge. The Noble County Sanitarian has knowledge of the sludge spreading practice (see Public Attitudes) and approves of this disposal method.

There have been no reported adverse health effects affecting any person involved in the sludge disposal program. Inoculations are not given to the STP employees.

ECONOMICS

Under current agreement, the sludge hauling contractor receives $10 for each load hauled from the STP. The sludge is to be disposed only at the study site. For each load dumped, the contractor pays the farmer $1.

Records dating back to 1967 indicate that the contractor has hauled approximately 80 percent of the sludge for $9/load through 1975. (A second hauler employed at $10/load during segments of 1973 and 1974 accounted for the remaining 20 percent.) The rate was increased to $10/load on January 1, 1976.

Due to the nature of the agreement, the cost of disposal is directly dependent upon the hauling fee and the sludge solids. The current disposal cost is $26.47/dry m ton ($24.01/dry ton) based on 9.6 cu m (2,500 gal)/load and 4.0 percent sludge solids.

Chemical expenses for both ferric chloride and Floculite 550 were not included in the cost analysis of sludge disposal since they are used principally for precipitating phosphorus and achieving required suspended solids removal efficiencies.

SAMPLING AND ANALYSIS

Sludge

On May 27 and August 26, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the anaerobic sludge digester.

Soil

On May 27 and 28, 1976, surface and subsurface soil samples were obtained from both the treated and control plots, each being divided into five sections. Approximately 30 individual core samples from the surface 0 to 20 cm (0 to 8 in) were obtained per section with a 2.5 cm (1 in) diameter stainless steel split tube sampler.

An initial attempt was made to obtain subsurface samples using a 7.6 cm (3 in) diameter stainless steel bucket auger. However, all attempts were unsuccessful because of pebbles between the 30 and 61 cm (12 and 24 in) level. A truck-mounted 5 cm (2 in) diameter pneumatic core drill operated by the

369

resident soil conservationist was finally used to obtain the required samples. The surface 20 cm (8 in) was discarded from each core. Samples were then taken between 20 and 30 cm (8 and 12 in) and labeled Horizon A; 30 to 61 cm (12 to 24 in) Horizon B; 61 to 91 cm (24 to 36 in) Horizon C; and 91 to 122 cm (36 to 48 in) Horizon D. Four 122 cm (48 in) cores evenly spaced throughout were obtained from each section. As the cores were removed from the sample tube, each was carefully placed on a clean plastic tarp, measured and cut, and placed in premarked plastic sample bags. Subsurface soil samples were obtained from both treated and control plots in an identical manner.

Plants

On May 27, 1976, alfalfa samples were obtained from both plots by cutting and retaining the top 20 to 25 cm (8 to 10 in) of plants with a pair of cutting shears. The alfalfa grew in clusters in both fields so that each cutting contained an estimated 10 plant samples. Any other trimmed tissue such as clover or orchard grass was removed prior to placing the alfalfa in a sample bag. Approximately 15 such cuttings were taken from each section, resulting in an estimated 2 kg (4 lb) sample from each section.

Tables 114 through 121 present the following:

Table	Description
114	Chemical Characterization of Stabilized Sludges
115	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
116	Total Metal Concentrations in Individual Surface Soil Samples
117	Selenium in Composite Plants and Soils
118	Metal Concentrations in Surface Soils and Plants
119	Chlorinated Hydrocarbon Concentrations
120	Parasites in Sludges, Plants, and Soils
121	Concentrations of Microbes in Sludges, Soils, and Plants

Figures 86 to 95 present particle size analyses of the various soil composites by depth.

TABLE 114

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM KENDALLVILLE, INDIANA

	5/27/76	8/26/76	Average
Volatile Solids (%)	33.08	39.13	36.1
NO_3 - N	<1.88	6.21	4.05
NH_4 - N	3031	2483	2757
Organic N	18765	10836	14801
P	19375	8741	14058
K	7925	2584	5255
Na	9250	3776	6513
Ca	39625	11922	25774
Mg	17992	6522	12257
SO_4	n.d.	<17.2	<8.6
Cl	7734	5690	6712
Ag	15.2	5.26	10.2
As	7.19	3.02	5.11
B	61.6	25.9	43.8
Cd	76.1	23.8	50.0
Cr	3023	998	2011
Co	35.2	14.6	24.9
Cu	1038	431	734
Fe	71766	24440	48103
Hg	3.13	3.02	3.08
Mn	14969	4767	9868
Mo	10.6	4.48	7.54
Ni	108	46.7	77.3
Pb	12609	2348	7479
Se	22.0	12.3	17.2
Zn	11006	3371	7188
H_2O (%)	93.6	88.4	91.0
pH	7.5	7.6	

All units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 115

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

KENDALLVILLE, INDIANA

PLOT/ DEPTH	TOTAL METALS (2)					DTPA EXTRACTABLES			
	CD	CU	NI	ZN	PB	CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	0.52	21.8	26.5	113	32.9	0.27	5.92	2.29	27.2
20-30 CM.	0.16	19.6	37.3	64.8	12.9	0.14	2.46	1.40	4.63
30-61 CM.	0.25	21.0	44.9	67.0	13.0	0.12	1.10	1.28	1.02
61-91 CM.	0.46	21.3	44.6	65.7	13.0	0.11	0.95	1.27	1.06
91-122 CM.	0.60	19.7	43.4	63.9	14.5	0.11	0.95	1.27	0.92
CONTROL									
SURFACE	0.29	11.5	20.6	55.0	11.3	0.17	1.50	1.82	2.81
20-30 CM.	0.22	14.6	28.2	60.3	11.0	0.16	1.46	1.55	1.66
30-61 CM.	0.28	19.9	38.0	66.9	12.2	0.13	1.21	1.16	1.08
61-91 CM.	0.55	19.4	40.6	61.9	12.3	0.13	0.95	1.21	0.59
91-122 CM.	0.51	18.5	37.7	57.6	12.8	0.11	0.89	1.22	0.89

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 116

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES (1)

KENDALLVILLE, INDIANA

SECTION/ DEPTH	TREATED CD	TREATED CU	TREATED NI	TREATED ZN	CONTROL CD	CONTROL CU	CONTROL NI	CONTROL ZN
	µG/G				µG/G			
SECTION 1								
20-30 CM.	0.20	20.3	35.3	77.6	0.34	18.7	36.4	63.9
30-61 CM.	0.38	17.3	39.9	62.9	0.51	20.3	40.3	62.0
61-91 CM.	0.44	19.0	47.5	66.1	0.90	17.8	44.1	59.1
91-122 CM.	0.96	18.0	53.0	62.1	0.90	18.0	42.2	52.1
SECTION 2								
20-30 CM.	0.12	20.0	40.8	68.4	0.18	14.7	25.9	60.3
30-61 CM.	0.35	22.1	51.9	69.5	0.28	19.2	32.7	61.5
61-91 CM.	0.58	20.4	49.6	66.5	0.92	20.9	39.0	62.8
91-122 CM.	0.79	19.9	50.8	70.9	0.33	20.4	41.4	63.8
SECTION 3								
20-30 CM.	0.24	22.7	33.4	78.5	0.23	14.1	25.9	67.9
30-61 CM.	0.34	21.1	44.3	66.2	0.15	17.6	34.0	68.8
61-91 CM.	0.47	21.2	47.0	70.4	0.34	20.6	43.3	72.3
91-122 CM.	0.57	20.8	47.3	77.0	0.61	18.4	39.8	62.6
SECTION 4								
20-30 CM.	0.05	17.1	30.4	58.2	0.30	13.8	25.8	60.2
30-61 CM.	0.19	21.0	47.1	65.5	0.30	23.0	44.2	72.3
61-91 CM.	0.57	20.0	49.0	62.8	0.47	19.7	45.7	63.9
91-122 CM.	0.60	19.6	46.7	61.8	0.54	18.4	43.8	61.3
SECTION 5								
20-30 CM.	0.15	23.7	46.1	70.8	0.25	15.3	29.7	60.1
30-61 CM.	0.25	22.6	48.8	72.3	0.22	20.7	41.1	69.4
61-91 CM.	0.27	24.5	49.6	73.3	0.79	19.2	48.3	60.1
91-122 CM.	0.71	18.6	49.6	56.6	0.66	15.6	41.9	52.0

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 117

SELENIUM IN COMPOSITE PLANTS AND SOILS

KENDALLVILLE, INDIANA

	Treated Plot	Control Plot
	µg/g	
Plant (alfalfa)	<0.02	<0.02
Soil (depth in cm)		
0-20	<0.02	<0.02
20-30	<0.02	<0.02
30-61	<0.02	<0.02
61-91	<0.02	<0.02
91-122	<0.02	<0.02

TABLE 118

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS[1]

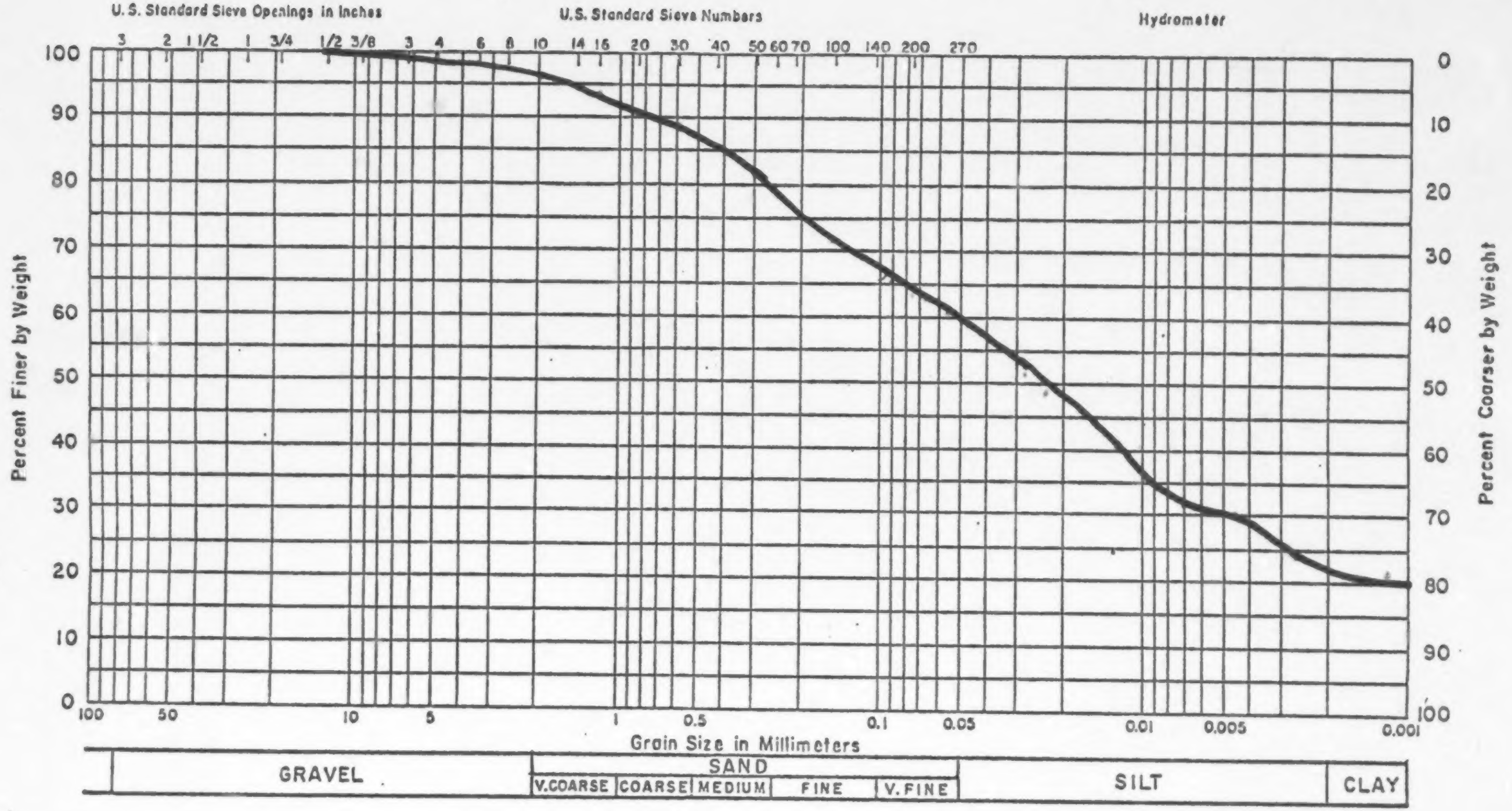
KENDALLVILLE, INDIANA

SAMPLE	SURFACE SOIL CD	SURFACE SOIL CU	SURFACE SOIL NI	SURFACE SOIL ZN	SURFACE SOIL PB[2]	PLANT CD	PLANT CU	PLANT NI	PLANT ZN	PLANT PB[2]	PLANT ORG-N[2]
	μG/G					μG/G					
TREATED											
COMPOSITE	0.52	21.8	26.5	113	32.9	0.89	8.48	6.44	78.1	5.42	3.99
SECTION 1	0.72	27.8	27.9	146		0.74	9.77	6.63	61.9		
SECTION 2	0.27	21.7	28.0	102		0.89	10.70	7.76	145.0		
SECTION 3	0.26	21.1	26.5	115		0.65	8.98	7.28	57.8		
SECTION 4	0.19	21.8	29.7	96.8		0.68	8.23	6.78	73.9		
SECTION 5	0.38	22.3	31.3	130		0.74	8.88	6.63	76.6		
MEAN	0.36	22.9	28.7	118		0.74	9.31	7.02	83.0		
STD. DEV.	0.21	2.75	1.85	20.26		0.09	0.95	0.49	35.5		
CONTROL											
COMPOSITE	0.29	11.5	20.6	55.0	11.3	0.74	8.83	5.37	37.6	5.86	4.37
SECTION 1	0.23	12.2	24.1	57.5		0.62	7.77	6.95	31.5		
SECTION 2	0.17	11.5	21.8	57.4		0.63	8.46	6.84	37.2		
SECTION 3	0.31	11.6	22.3	63.7		0.57	9.72	6.78	40.0		
SECTION 4	0.19	11.6	21.9	58.0		0.61	8.28	6.63	37.8		
SECTION 5	0.10	11.8	21.5	56.0		0.57	8.08	6.29	35.9		
MEAN	0.20	11.7	22.3	58.5		0.60	8.46	6.70	36.5		
STD. DEV.	0.06	0.28	1.04	2.99		0.03	0.75	0.26	3.15		

---

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

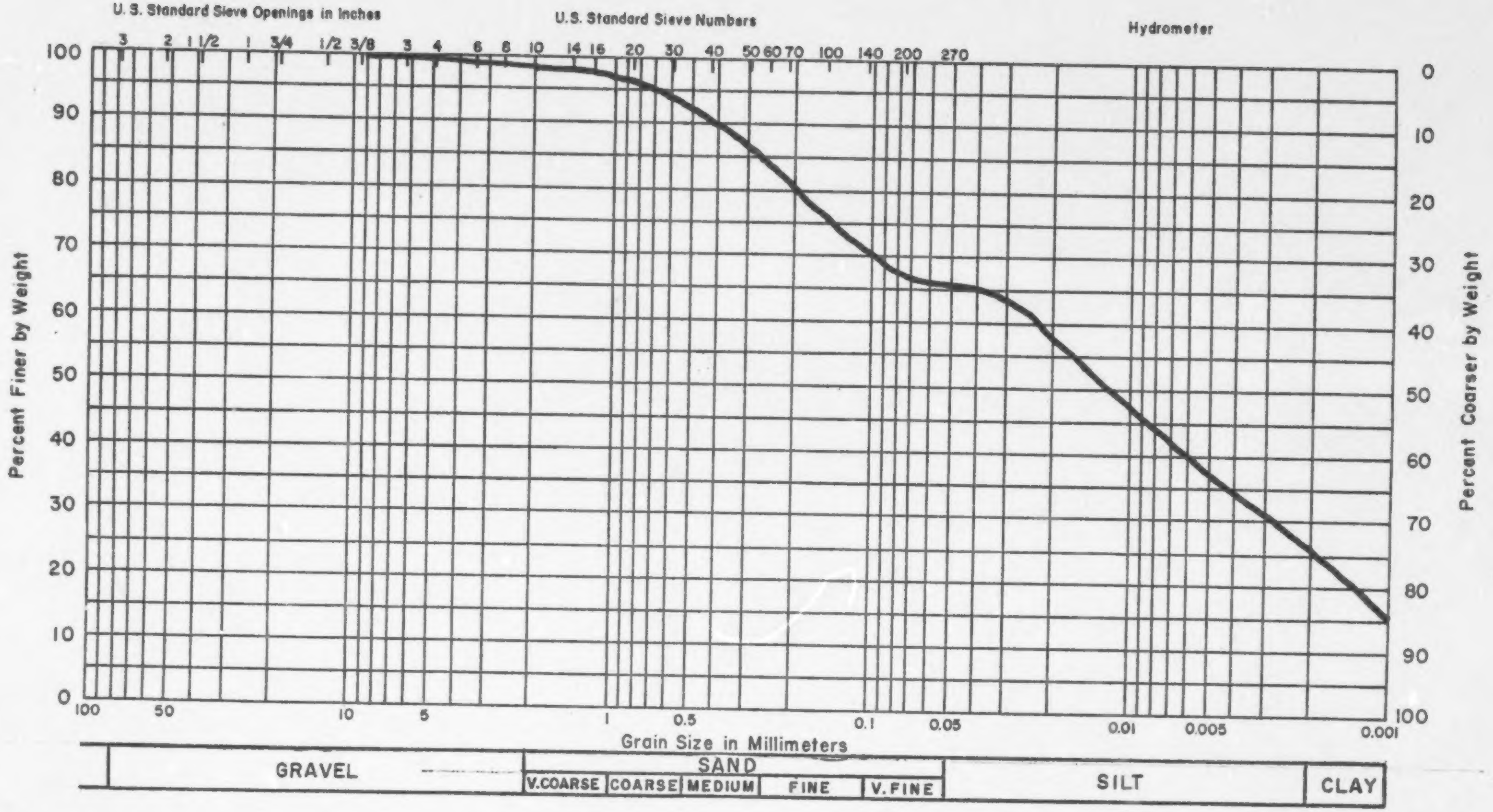
(2) ANALYSIS ON COMPOSITE ONLY.



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
962	Kendallville	39	33	28	Clay Loam
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

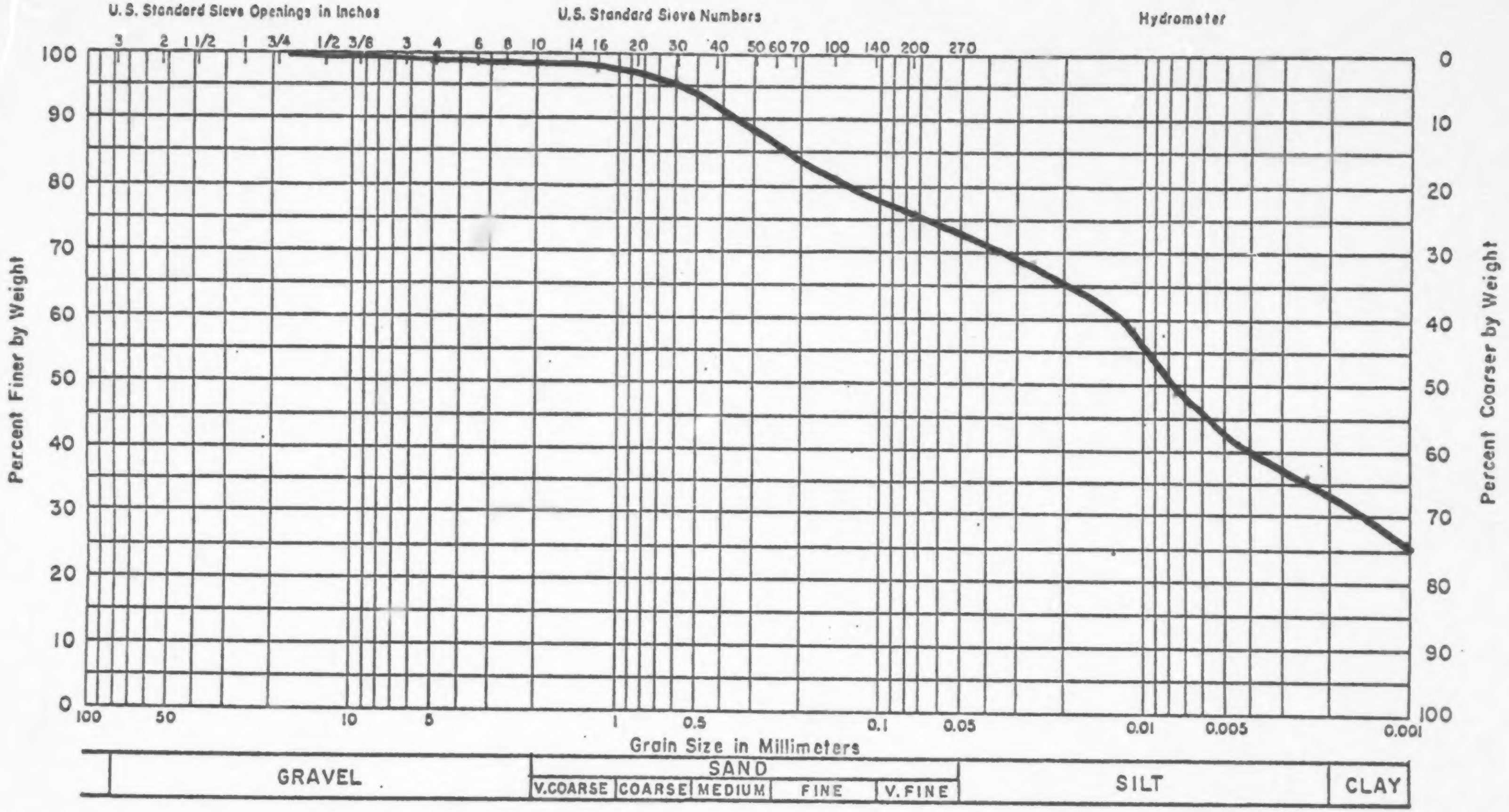
Figure 86 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
968	Kendallville	31	40	29	Clay Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

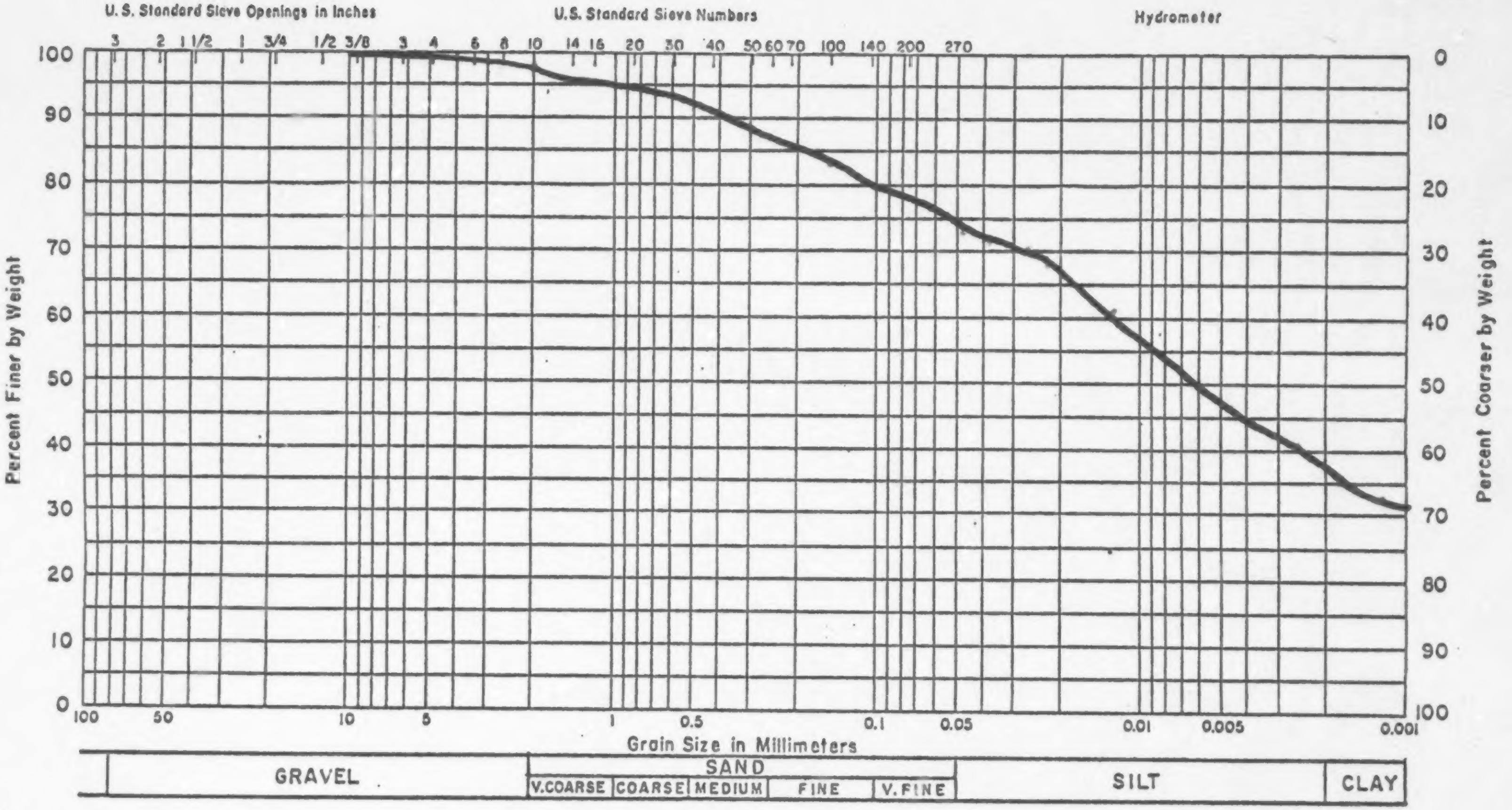
Figure 87 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
974	Kendallville	28	40	32	Clay Loam
	Treated				
	20-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

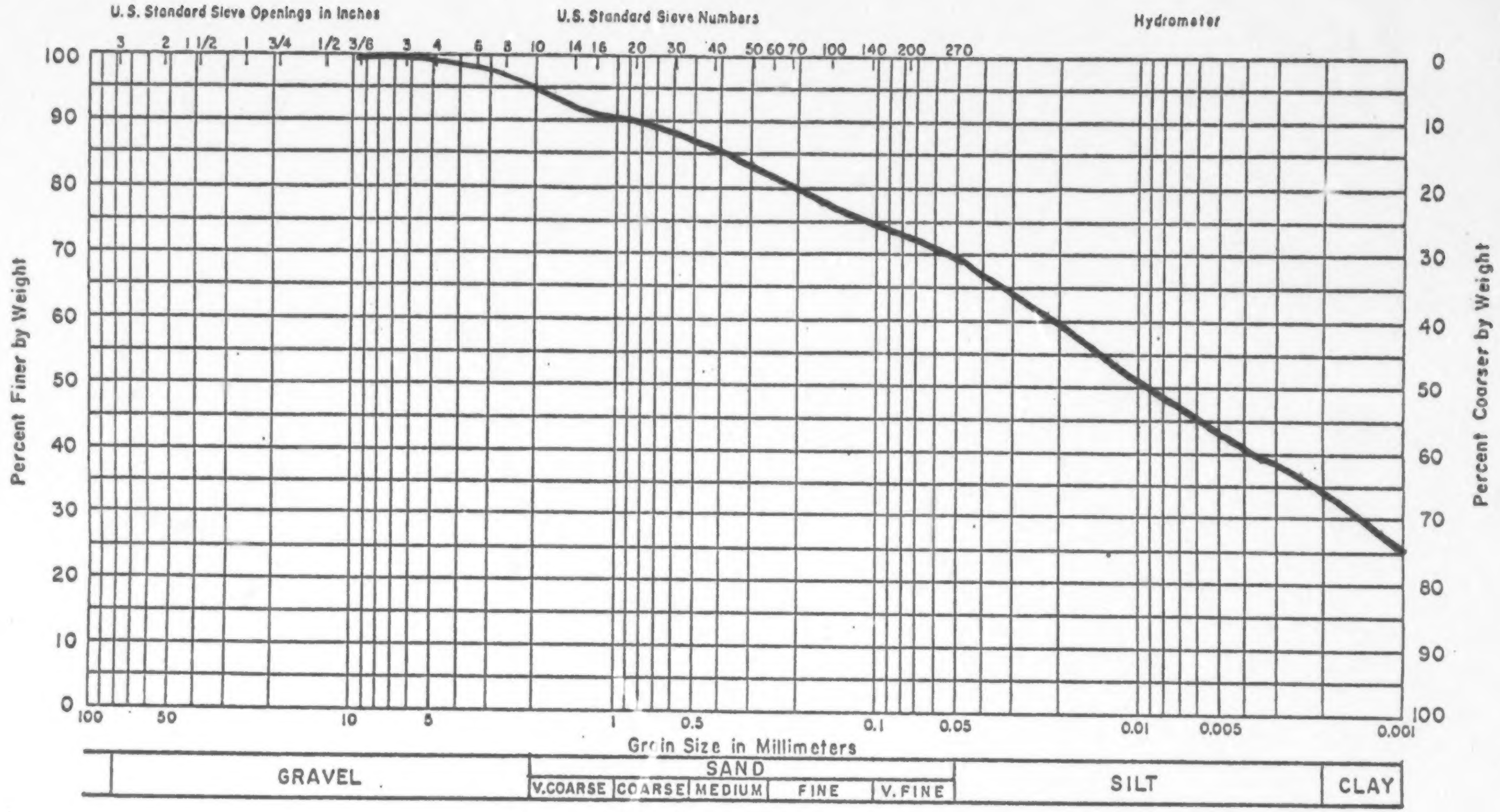
Figure 88 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
980	Kendallville Treated 30-61 cm	24	37	39	Clay Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 89 Kendallville, IN, Particle Size Analysis

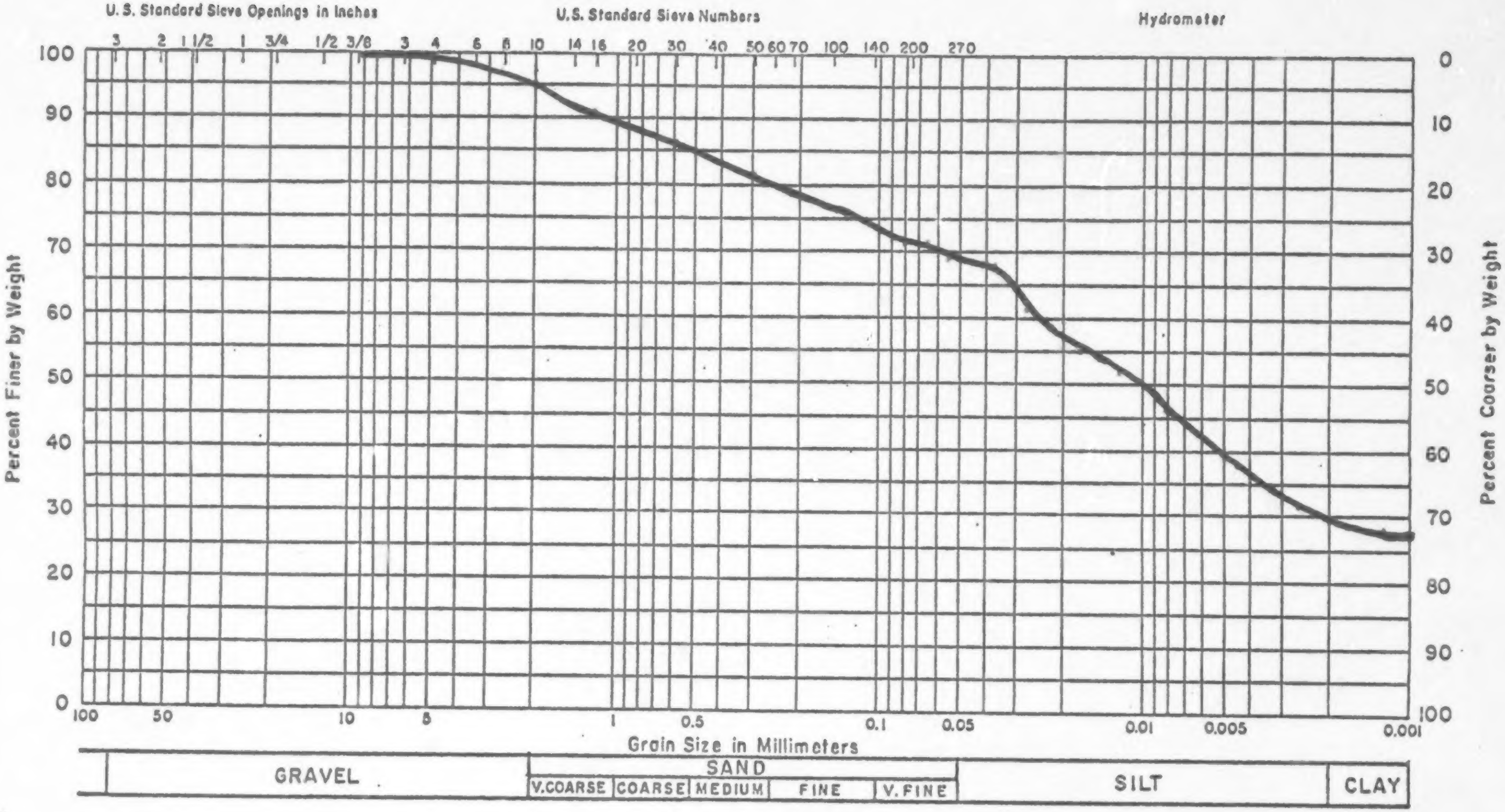


SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
986	Kendallville	26	39	35	Clay Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 90 Kendallville, IN, Particle Size Analysis

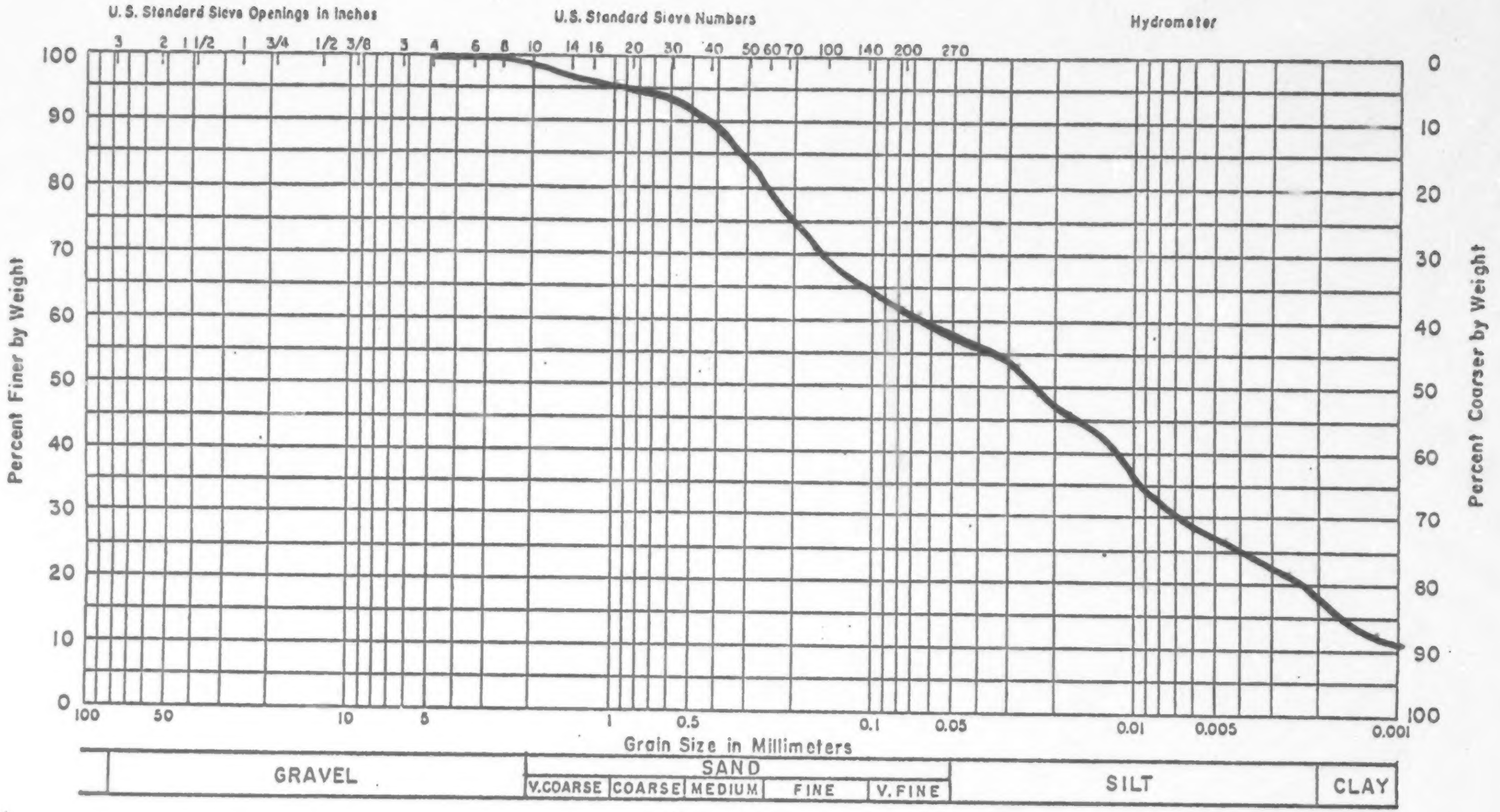
381



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
992	Kendallville Treated 91-122 cm	28	41	31	Clay Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

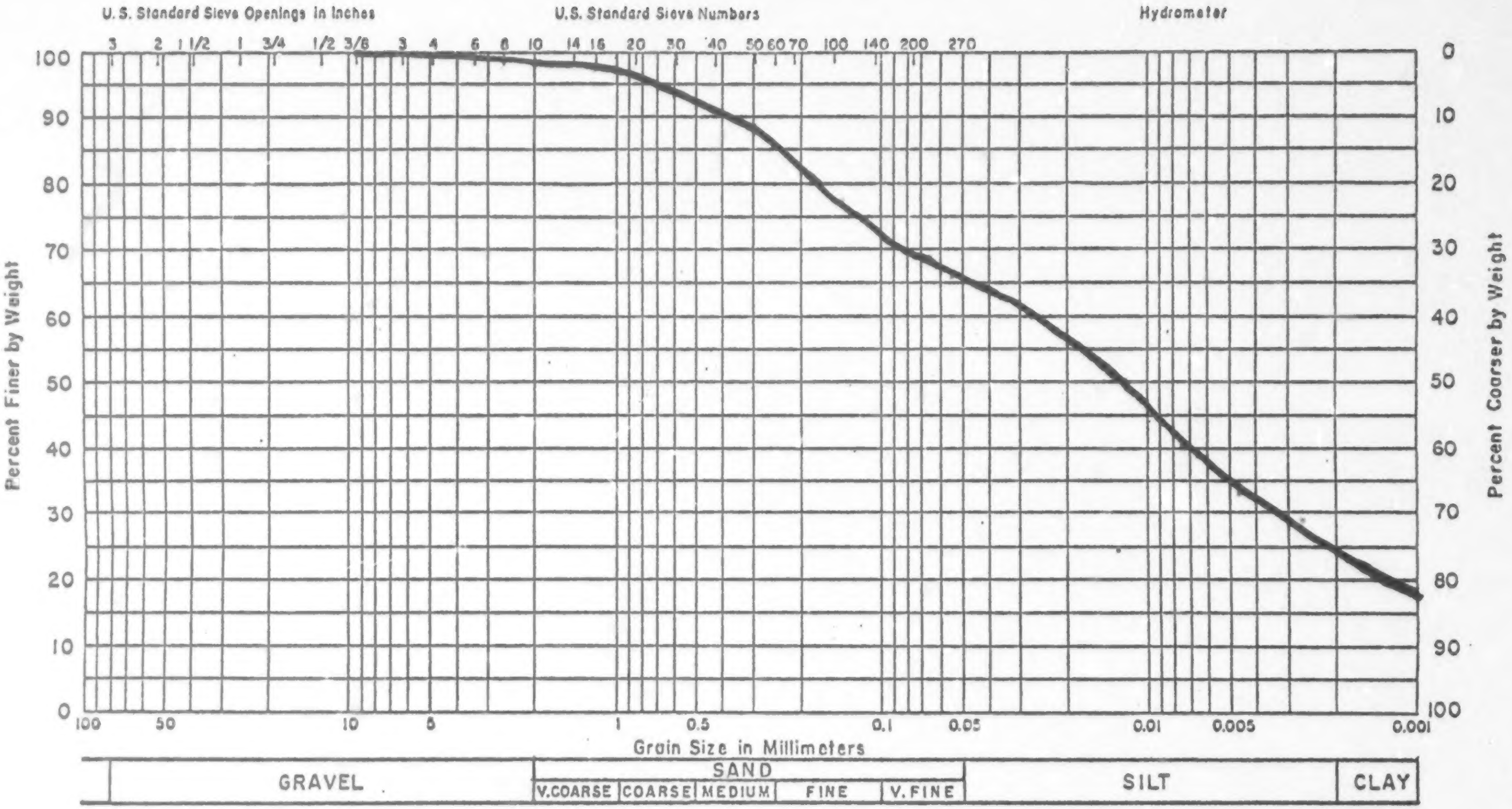
Figure 91 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
938	Kendallville Control Surface	40	41	19	Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

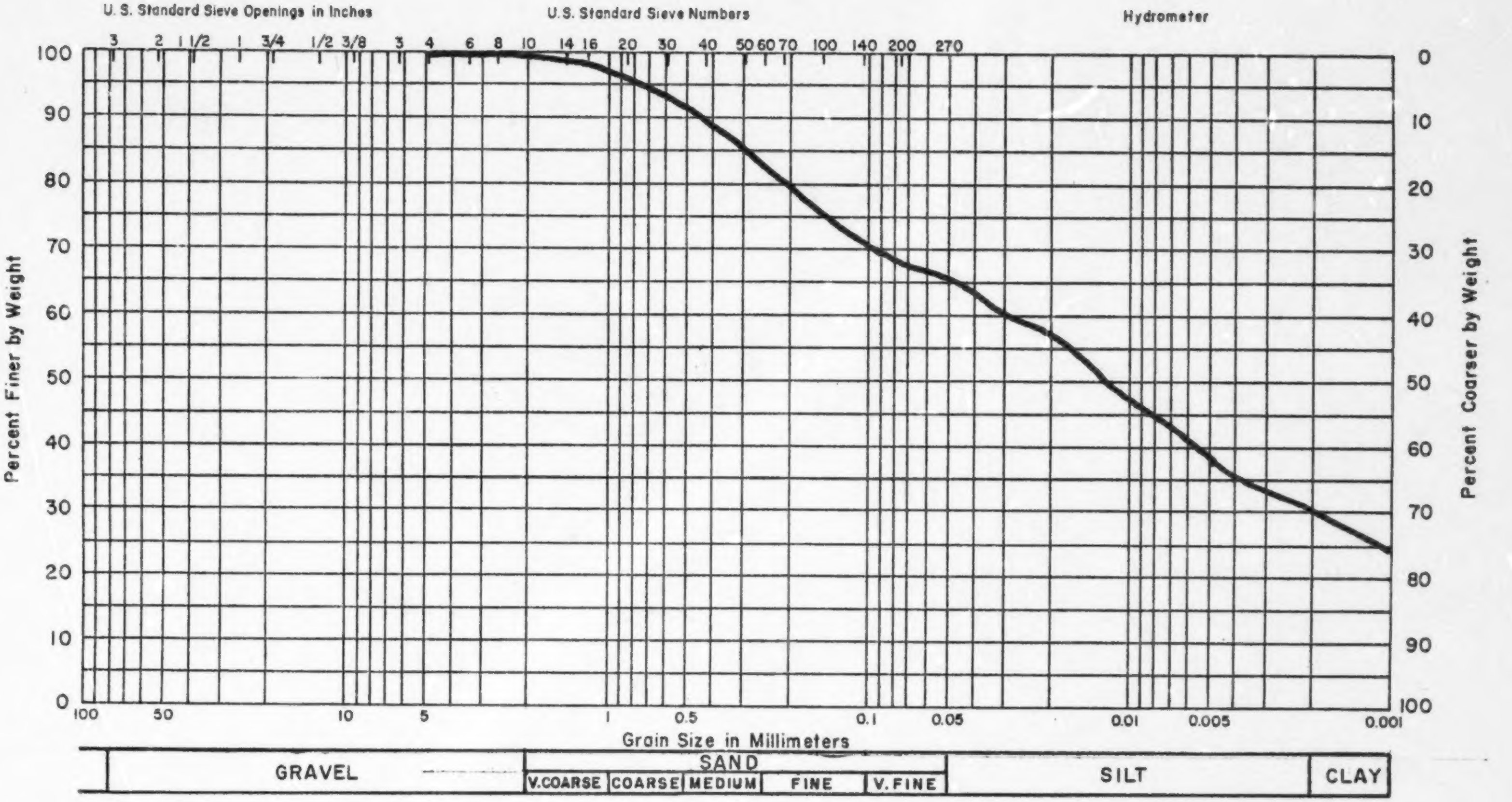
Figure 92 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
944	Kendallville	34	42	24	Loam
	Control				
	20-30 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

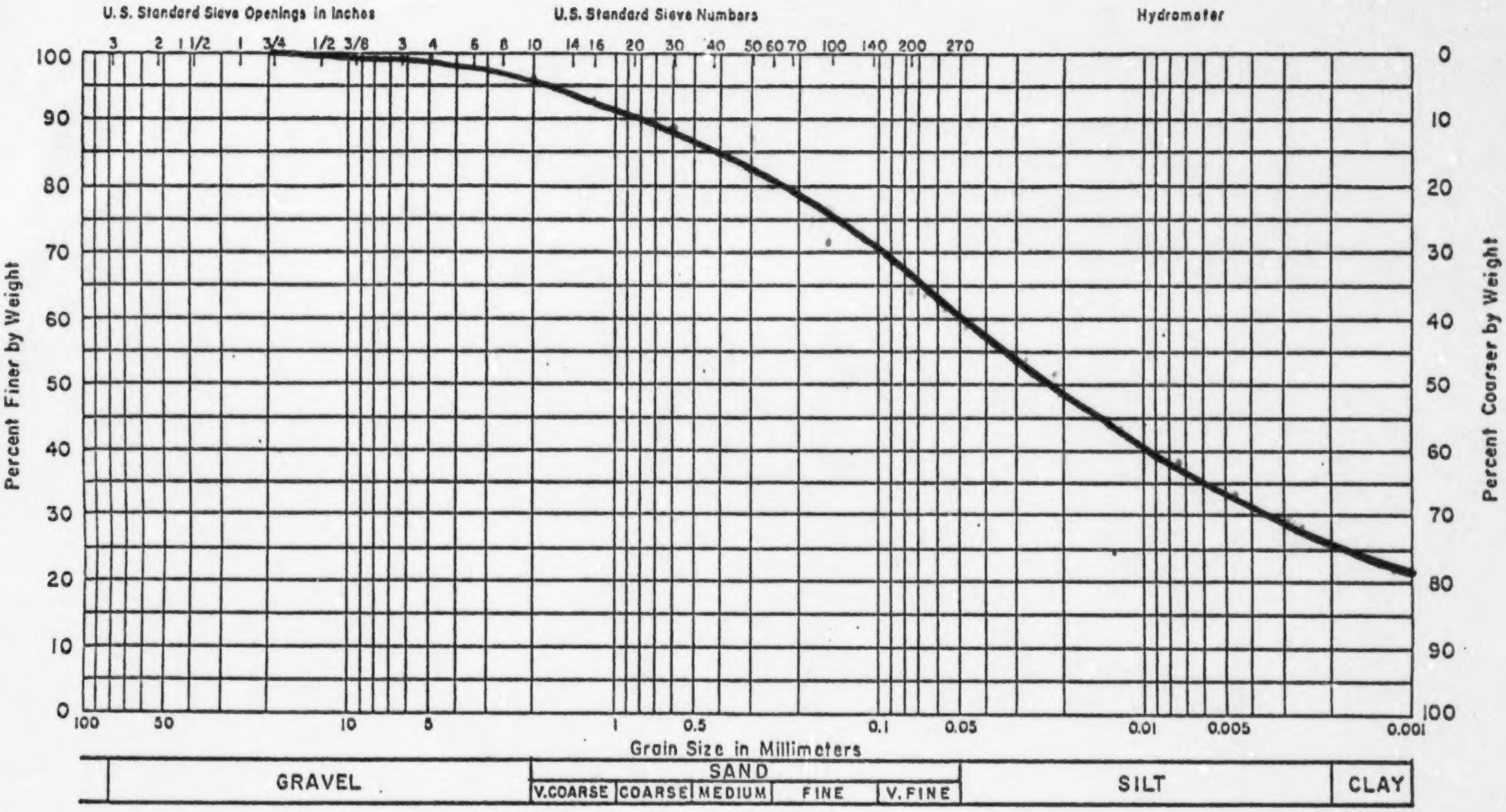
Figure 93 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
950	Kendallville	34	36	30	Clay Loam
	Control				
	30-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 94 Kendallville, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
956	Kendallville	39	35	26	Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHM
CONSULTING ENGINEERS, I
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 95 Kendallville, IN, Particle Size Analysis

TABLE 119

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

KENDALLVILLE, INDIANA

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . µg/kg	. . . .	
Soil			
Surface Composites	0.29	<0.01[1]	DDT
	0.08	<0.02	DIELDRIN
	300	<1	PCB 1221
	<1	<1	PCB 1248
Plant			
Composites	<0.02	<0.02	DDT
	<0.04	<0.04	DIELDRIN
	<1	<1	PCB 1221
	<0.11	<0.11	PCB 1248
	(5/27/76)	(8/26/76)	
Stabilized Sludge	<1.56	<1.90	DDT
	5.78	<5.17	DIELDRIN
	<1.0	<1.0	PCB 1221
	3672	449	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

See pg 44 [illegible] value

TABLE 120

PARASITES IN SLUDGES, SOILS, AND PLANTS

KENDALLVILLE, INDIANA

Sample Description	Results
Sludge	
Raw (5/27/76)	Negative
Raw (8/26/76)	Negative
Stabilized (5/27/76)	Negative
Stabilized (8/26/76)	Negative
Plants	
Treated	Negative
Control	Negative
Soils - Treated Composites	
Surface	Negative
20-30 cm	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
20-30 cm	Negative
30-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 121

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
KENDALLVILLE, INDIANA

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 5/27	1.4×10^7	ND	+	+	-	ND	+	+	-	3.1×10^4	+	+	+	1.2×10^7	+	+	+
Raw 8/26	1.4×10^{10}	ND	+	-	-	ND	+	-	-	ND	+	-	-	2.4×10^6	+	+	+
Stab 5/27	1.11×10^9	ND	+	+	-	ND	+	+	-	2.7×10^4	+	+	+	1.2×10^7	+	+	+
Stab 8/26	6.56×10^9	ND	+	-	-	ND	+	-	-	ND	+	-	-	4.4×10^6	+	+	+
Plants																	
Treated	1.06×10^9	ND	+	+	-	ND	+	+	-	1.4×10^4	+	+	+	2.5×10^4	+	+	+
Cotnrol	1.72×10^{10}	ND	+	+	-	ND	+	+	-	1.9×10^4	+	+	+	1.9×10^4	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

VIII-13

TABLE 121 (Continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
	(10^6)																
Soils - Treated Composites																	
Surface	6.32	ND	+	+	-	ND	+	+	-	4.6	+	+	+	5	+	+	+
20-30 cm	6.40	ND	+	+	-	ND	+	+	-	ND	+	-	-	10	+	+	+
30-61 cm	2.94	ND	+	+	-	ND	+	+	-	ND	+	-	-	4	+	+	+
61-91 cm	3.69	ND	+	+	-	ND	+	+	-	ND	+	-	-	5	+	+	+
91-122 cm	3.56	ND	+	+	-	ND	+	+	-	ND	+	-	-	ND	+	-	-
Soils - Control Composites																	
Surface	7.13	ND	+	+	-	ND	+	+	-	ND	+	-	-	ND	+	+	-
20-30 cm	5.86	ND	+	+	-	ND	+	+	-	ND	+	-	-	4	+	+	+
30-61 cm	2.99	ND	+	+	-	ND	+	+	-	ND	+	-	-	4	+	+	+
61-91 cm	3.07	ND	+	+	-	ND	+	+	-	ND	+	-	-	5	+	+	+
91-122 cm	1.82	ND	+	+	-	ND	+	+	-	ND	+	-	-	9	+	+	+

[1] All results expressed on a dry weight basis.

*Values expressed as a power of 10 (i.e., 10^4).

**Observations reported as + or -.

ND = none detected.

CHAPTER IX

COLUMBUS, INDIANA

SITE DESCRIPTION

Location

This study site is approximately 1.6 km (1 mi) south of Columbus, Indiana. The sludge-treated field is located adjacent to the Columbus Treatment Plant (STP) located at 327 Water Street. The primary control field is approximately 0.8 km (0.5 mi) south of the treated field. A second control field from which only corn grain samples were taken is located directly south of the primary control field.

Physical Conditions

Columbus is typical of the many farming communities in south-central Indiana: terrain is flat to gently rolling, and principal crops are corn, soybeans, and other feed grains.

The treated plot, measuring approximately 300 x 20 m (1,000 x 100 ft) is situated on a 14.2 ha (35 acre) field adjacent to the STP (Figure 96) and slopes downward from south to north. The long and narrow rectangular shape of this plot was dictated by the presence of several different soil series within the field. Establishment of this rectangular configuration allowed all sampling to be performed within one soil series. The outer boundary line of treated plot coincides with the edge of the field. Haw Creek, which forms a natural boundary for the 14.2 ha (35 acre) field, is south and below the plot.

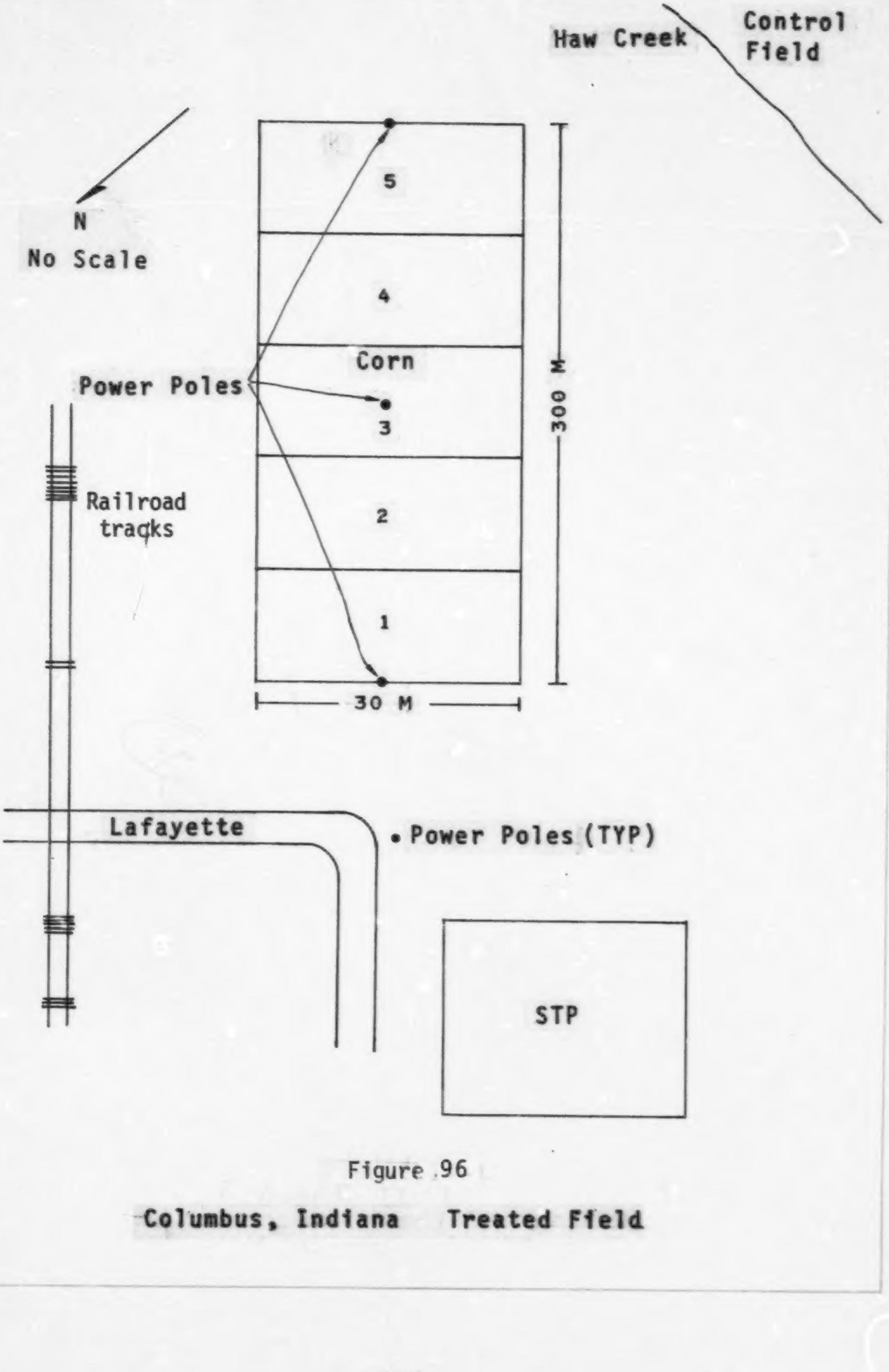

Haw Creek
Control Field
N
No Scale
5
4
Corn
Power Poles
3
2
1
Railroad tracks
300 M
30 M
Lafayette
• Power Poles (TYP)
STP

Figure 96

Columbus, Indiana Treated Field

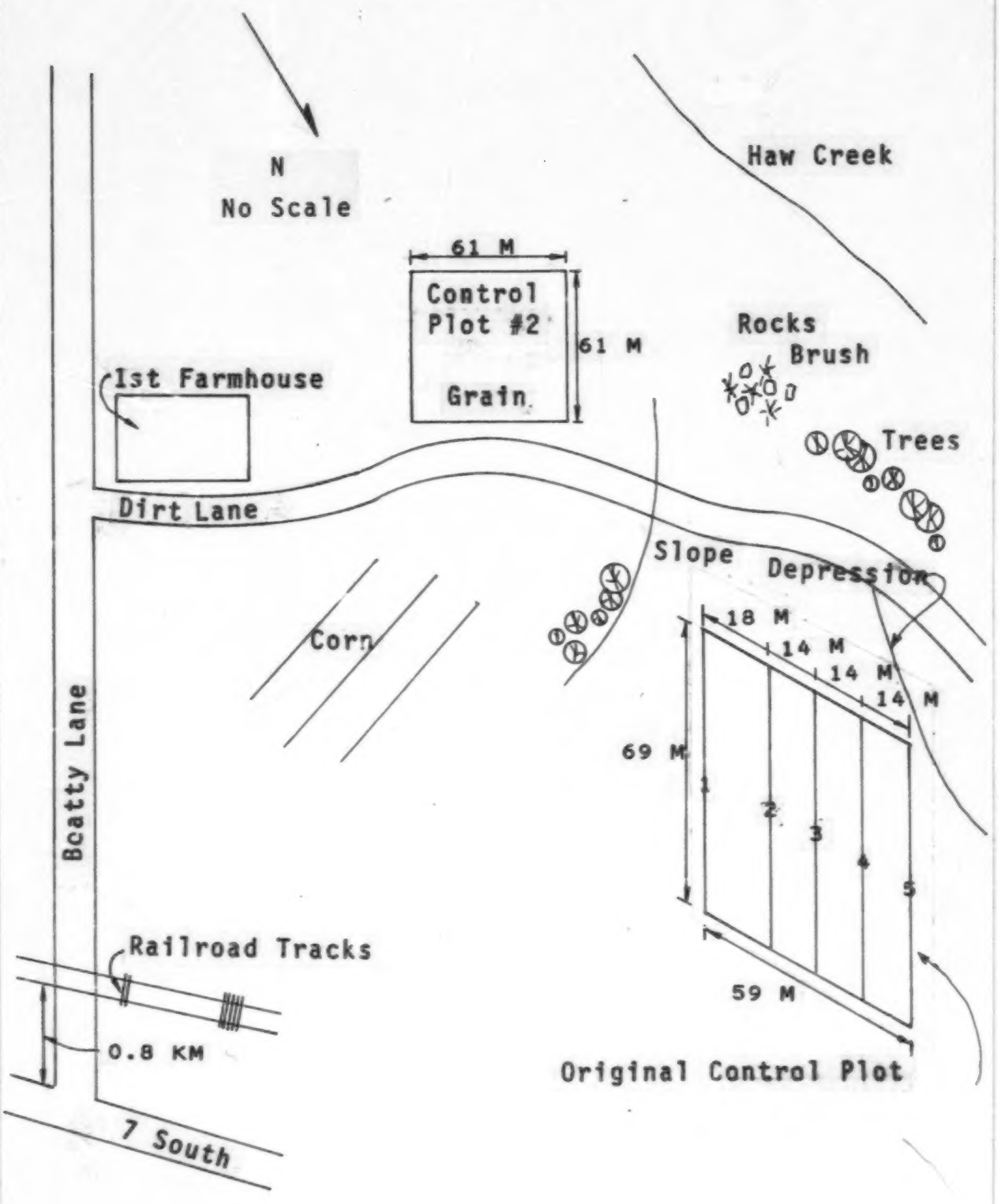
392

Both control fields are approximately 0.8 km (0.5 mi) across Haw Creek. The original control plot was the source of leaf and soil samples. It is in the shape of a parallelogram (Figure 97) measuring approximately 69 x 59 m (225 x 195 ft). The second control plot was selected because the first field was harvested before grain samples could be obtained. This second plot is located approximately 275 m (300 yd) south of the original control plot. This plot was estimated to be approximately 0.4 ha (1 acre) in size; it was not divided into sections because only one field composite was required.

Groundwater levels in the vicinity of the treated field are estimated to be at 4.6 to 5.5 m (15 to 18 ft) below ground surface.

Farming Practices

Before 1971, the treated field had always been planted in corn which was sold to a distillery. Starting in 1971 and continuing through early 1975, however, this land was leased to the STP to serve as a disposal area for liquid sludge. In 1975 the field was again planted with distillery-bound corn (Zea Mays, L.), which was also planted in 1976 and was the crop sampled on July 13 and 14, 1976. Because the low areas of the field had field-dried sludge ranging from a thin crust to pockets as thick as 30 cm (12 in), soil preparation prior to the 1975 corn crop required the use of heavy earth-moving machinery. (See Disposal of Sewage Sludge for details about application rates and methods.) The dried sludge and soil were reworked to



N
No Scale
Haw Creek
61 M
Control
Plot #2
61 M
Grain
Rocks
Brush
Trees
1st Farmhouse
Dirt Lane
Slope
Depression
Corn
18 M
14 M
14 M
14 M
69 M
1
2
3
4
5
59 M
Beatty Lane
Railroad Tracks
0.8 KM
Original Control Plot
7 South

Figure 97

Columbus, Indiana Control Field

form a sufficiently firm base that would support a stand of corn.

Field preparation typically begins in the fall with chisel plowing to a depth of 30 cm (12 in) followed by applications of phosphate at 56 kg/ha (50 lb/acre) and potash at 134 kg/ha (120 lb/acre). In the spring the field is disked twice to a depth of 20 cm (8 in), and then seeded. The corn is allowed to grow to a height of almost 30 cm (12 in), and anhydrous ammonia is applied at 224 kg/ha (200 lb/acre). 1975 provided an exception to this cultivation schedule, however, because fertilizers were not used.

If necessary, the field is spot-sprayed with Banvel for weed control. In 1975, the insecticide Heptachlor at 5.6 kg/ha (5 lb/acre) was applied. In 1976, 20 percent Aldrin at 5.6 kg/ha (5 lb/acre) was used. The soil on the treated field has had a history of lime applications to maintain a pH level of between 6.5 and 6.8. Lime, however, has not been applied within the last five years.

Though the normal yield for corn in the Columbus area is approximately 125 bu/acre, the first corn crop from the treated field in 1975 yielded only 35 bu/acre. The farmer of the field believes there were three principal reasons for the low yield:

1. Excess sludge in the lower spots of the field prevented seed germination even though the surface soil and sludge deposits had been worked together.

2. The heavy loadings of sludge throughout the field prevented the surface soil from drying, consequently delaying planting of the crop by an estimated 3 to 4 weeks; and
3. No fertilizer was added to the crop to stimulate growth.

The 1976 yield was an estimated 90 bu/acre. The farmer again cited late planting due to the slow drying time of the field as the principal reason for the lower yield. Comparable 1976 yields in the area averaged 30 bu/acre.

The control plots are owned by two separate farmers. Soil preparation and farming techniques utilized are similar to those of the treated field, but anhydrous ammonia is added at a reduced rate: 112 kg/ha (100 lb/acre). In addition, the herbicide Aatrex 4L is usually applied at 0.8 l/ha (0.5 gal/acre). Lime has not been used within the last five years.

Yields were not available for either control plot. All three plots were observed at the time of sampling to have abundant growths of corn that had passed the tasseling stage with young ears averaging 5 to 8 cm (2 to 3 in) in length. The crop at the treated plot was, however, slightly less mature than at the control plot, probably due to a difference in planting dates.

CLIMATE

The climate near Columbus is continental, with rather warm summers, moderately cold winters, and occasional wide variations in temperature, particularly during the fall and winter. Periods of humid, muggy weather occur during the summer. Hot, dry winds will occasionally prevail from the west or southwest for several days.

Precipitation is normally adequate for good crops and is well distributed throughout the year. Snowfalls of 8 cm (3 in) or more usually occur two or three times during the winter.

The average freeze-free period extends from April 23 to October 22. However, freezing temperatures have occurred as late as May 27 and as early as September 27.

Additional meteorological data are presented in Table 122.

SOIL DESCRIPTION

All three fields selected for sampling are characterized by one soil series - Ross. The Ross series, consisting of deep, well-drained, nearly level soils on bottom lands, forms in medium-textured and moderately fine-textured neutral alluvium. In a representative profile, the surface layer is dark brown, silty clay loam about 76 cm (30 in) thick. The underlying material is dark yellowish-brown, friable loam about 38 cm (15 in) thick. Below this, to a depth of about 183 cm (72 in) is dark yellowish-brown, stratified sand and sandy loam.

Ross soils are high in organic matter content with high water-holding capacity and moderate permeability. The soils are subject to flooding, mainly in winter and early in spring but also occasionally during the growing season. Runoff is low.

TABLE 122

COLUMBUS, INDIANA

Meteorological Data For The Current Year

Station: Indianapolis, Indiana Standard time used: EASTERN Latitude: 39° 44' N Longitude: 86° 17' W Elevation (ground): 792 feet Year 1975

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity, pct.				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Averages			Extremes						Water equivalent			Snow, Ice pellets			Hour	Hour	Hour	Hour	Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F				Elev. 808 feet m.s.l.
																																			Maximum		Minimum		
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date	01 (Local time)	07	13	19	Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy					(h) 90° and above	32° and below	32° and below	0° and below	
JAN	39.7	24.3	32.0	65	29	6	20	1016	0	4.37	1.03	10	6.8	2.1	19	86	88	76	78	23	5.4	11.9	49	SW	10	38	7.8	4	7	20	16	2	4	2	0	8	27	0	988.5
FEB	38.8	25.2	32.0	55	21	-4	10	918	0	4.13	2.38	22-23	4.8	2.1	8-9	81	84	76	78	25	2.5	12.2	45	W	25	40	8.0	4	4	20	16	1	3	5	0	5	22	2	987.1
MAR	45.9	27.8	36.9	74	21	6	15	866	0	4.16	1.13	28-29	10.5	5.3	14	82	86	69	70	27	2.1	12.6	32	SW	25	52	7.7	4	7	20	20	2	7	2	0	2	19	0	985.8
APR	59.9	39.2	48.9	79	17	23	5	481	3	4.14	1.94	23-24	0.1	0.1	3	75	78	56	58	06	0.4	11.3	33	NW	3	57	6.3	7	8	15	11	0	7	0	0	0	10	0	988.5
MAY	76.5	54.4	65.5	88	24	42	13	78	100	2.42	0.78	30-31	0.0	0.0		84	88	58	61	22	1.2	8.9	49	W	26	68	6.4	7	10	14	10	0	6	0	0	0	0	0	985.4
JUN	81.2	61.7	71.5	91	20	46	8	22	222	5.73	3.73	25	0.0	0.0		90	92	67	65	21	3.5	9.6	32	SW	17	64	6.1	10	6	14	8	0	6	0	1	0	0	0	986.8
JUL	84.0	63.0	73.5	91	2	48	14	8	281	4.63	1.99	6-7	0.0	0.0		90	92	63	68	26	1.4	6.4	26	N	27	70	4.7	12	12	7	7	0	9	1	2	0	0	0	987.1
AUG	84.9	67.3	76.1	91	23	56	7	0	355	4.68	0.99	13	0.0	0.0		93	95	69	75	23	2.2	6.9	34	NW	17	60	6.4	6	9	16	13	0	10	2	4	0	0	0	989.2
SEP	72.4	52.7	62.6	90	3	39	13	137	71	2.32	1.50	11-12	0.0	0.0		90	95	64	73	30	0.6	7.4	28	NE	24	52	6.4	8	9	13	8	0	3	3	1	0	0	0	990.2
OCT	67.8	44.0	55.9	86	13	30	31	288	14	2.80	1.02	8	0.0	0.0		87	93	59	68	23	1.3	8.6	31	N	17	66	5.5	10	9	12	7	0	1	1	0	0	2	0	990.9
NOV	56.1	36.7	46.4	77	6	19	28	551	0	3.63	1.17	30	4.5	2.9	26	89	92	70	80	21	5.6	10.2	39	SW	20	51	6.2	7	9	14	11	2	3	0	0	0	14	0	989.5
DEC	39.5	26.0	32.8	67	14	7	18	992	0	3.71	1.45	15	8.1	4.8	25-26	87	90	80	86	24	1.9	10.0	33	SW	14	31	8.0	4	3	24	13	4	1	1	0	10	26	0	991.2
YEAR	62.2	43.4	52.8	91	AUG 23	-4	FEB 10	5357	1046	46.72	3.73	JUN 25	34.8	5.3	MAR 14	86	89	67	72	23	2.1	9.7	49	W	MAY 26	56	6.6	83	93	189	140	11	60	17	8	25	120	2	988.4

TABLE 122 (Continued)

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches												Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days											Average station pressure mb.
	Normal			Extremes						Water equivalent							Snow, Ice pellets					Hour 01	Hour 07	Hour 13	Hour 19			Fastest mile ϕ					Sunrise to sunset							Temperatures °F Max.		Temperatures °F Min.		Elev. 808 feet m.s.l.
Month	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year	(Local time)				Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90° and above	32° and below	32° and below	0° and below	
(a)				17		17					36		36		33		44		33		16	16	16	16	27	14	31	31		32	33	44	44	44	36	34	33	33	16	16	16	16	3
J	36.0	19.7	27.9	70	1967	-20	1972	1150	0	2.86	12.69	1950	0.21	1944	3.47	1950	17.0	1968	10.3	1965	77	80	69	71	11.1	NW	90	W	1950	41	7.2	6	6	19	11	2	1	4	0	13	27	4	989.6
F	39.3	22.1	30.7	74	1972	-10	1965	960	0	2.36	5.35	1971	0.37	1947	2.38	1975	15.3	1965	12.5	1965	76	79	66	69	11.2	WNW	65	SW	1948	51	6.9	6	6	16	10	2	1	2	0	8	25	1	988.1
M	49.0	30.3	39.7	80	1974	-6	1960	784	0	3.75	10.74	1963	1.03	1941	3.05	1963	10.5	1975	5.6	1948	75	79	63	65	11.9	WNW	68	NW	1947	51	7.1	5	8	18	13	1	3	2	0	3	18	*	985.3
A	62.8	41.8	52.3	89	1970	18	1972	387	6	3.87	8.09	1964	1.07	1946	2.56	1961	4.0	1940	3.1	1953	72	77	55	57	11.5	SW	60	W	1956	55	7.0	6	7	17	12	*	5	1	0	0	6	0	986.6
M	72.9	51.5	62.2	93	1965	28	1966	159	72	4.08	10.10	1943	1.42	1964	3.53	1961	T	1966	T	1966	78	82	57	58	9.7	SW	68	W	1951	61	6.5	7	9	15	12	0	7	1	1	0	1	0	984.3
J	82.3	61.1	71.7	96	1962	42	1969	11	212	4.16	9.74	1942	1.07	1967	3.80	1963	0.0		0.0		80	82	58	59	8.5	SW	77	N	1946	68	6.1	7	11	12	10	0	8	1	4	0	0	0	985.8
J	85.4	64.6	75.0	99	1970	48	1975	0	310	3.67	8.11	1958	0.99	1961	4.18	1973	0.0		0.0		83	87	60	62	7.4	SW	57	W	1957	70	5.8	8	13	10	9	0	8	1	6	0	0	0	987.5
A	84.0	62.4	73.2	97	1964	41	1965	5	259	2.80	6.64	1949	0.68	1964	2.72	1949	0.0		0.0		86	90	61	65	7.2	SW	54	NW	1946	71	5.4	10	12	9	8	0	6	2	3	0	0	0	986.9
S	77.7	54.9	66.3	96	1964	34	1974	63	102	2.87	6.01	1955	0.24	1963	3.07	1961	0.0		0.0		84	90	59	66	8.1	SW	61	NW	1952	66	5.4	11	8	11	8	0	4	1	2	0	0	0	989.6
O	67.0	44.3	55.7	88	1971	20	1962	302	13	2.51	8.36	1941	0.17	1963	3.90	1959	1.2	1962	1.2	1962	80	87	57	64	8.9	SW	56	NW	1952	64	5.2	12	8	11	8	*	2	1	0	0	4	0	991.3
N	50.5	32.8	41.7	78	1961	4	1959	699	0	3.10	5.65	1972	0.89	1949	3.02	1955	8.3	1966	8.2	1966	81	85	67	73	10.7	SW	59	SW	1948	42	6.9	7	7	16	10	1	1	2	0	1	15	0	989.0
D	38.7	23.1	30.9	70	1970	-14	1963	1057	0	2.71	6.70	1957	0.47	1958	2.21	1971	27.5	1973	11.5	1973	81	83	73	77	10.5	SW	56	SW	1971	39	7.3	5	6	20	12	2	*	3	0	10	25	1	989.0
YR	62.2	42.4	52.3	99	JUL 1970	-20	JAN 1972	5577	974	38.74	12.69	JAN 1950	0.17	OCT 1963	4.18	JUL 1973	27.5	DEC 1973	12.5	FEB 1965	79	83	62	65	9.7	SW	90	W	JAN 1950	58	6.4	90	101	174	123	7	45	21	15	35	120	7	987.9

399

A representative profile of Ross silty clay loam as mapped by the Soil Conservation Service is described as follows:

- 0 to 17.8 cm (0 to 7 in) - Dark brown, silty clay loam; moderate, medium granular structure; firm; neutral.
- 17.8 to 33 cm (7 to 13 in) - Dark brown, silty clay loam; moderate, medium subangular blocky structure; firm; continuous, very dark grayish-brown and very dark brown organic coatings on faces of peds; neutral.
- 33 to 76.2 cm (13 to 30 in) - Dark brown silty clay loam; moderate, fine and medium, subangular blocky structure; firm; continuous very dark grayish-brown organic coatings on faces of peds; neutral.
- 76.2 to 94 cm (30 to 37 in) - Dark yellowish-brown loam; weak, medium and coarse, subangular blocky structure; friable; discontinuous, very dark grayish-brown organic coatings mainly on vertical faces of peds; neutral.
- 94 to 114 cm (37 to 45 in) - Dark yellowish-brown loam; massive; friable; neutral.
- 114 to 183 cm (45 to 72 in) - Dark yellowish-brown stratified sand and sandy loam; massive; loose; neutral in upper part and moderately alkaline (calcareous) below a depth of 165 cm (68 in).

Treated Plot

The treated plot is mapped as Ross silt loam but while the soil has a profile similar to that described above, the surface layer is a friable silt loam. Included with this soil are some areas that have a surface layer of loam and other smaller areas that have a surface layer of silty clay loam. In a few places, there are small areas that have loose gravel at a depth of less than 100 cm (39 in).

Observations to the 122 cm (48 in) level during sampling indicated that the treated plot soil closely followed the above description. Identification of the surface 0 to 20 cm (0 to 8 in) was difficult, however, due to the large quantities of field-dried sludge intermixed with the original topsoil.

Control Plot

The parallelogram-shaped control plot from which soil and leaf samples were taken is also mapped as Ross silt loam. Observations at the time of sampling indicated a close similarity to the previously-described profile, with the exception of a sand layer encountered all along the 69 m (225 ft) Section 1 Line at the 61 cm (2 ft) level.

The soil at the plot from which the mature grain samples were obtained is mapped as Ross silty clay loam. It is described in the Bartholomew County, Indiana, Soil Survey (May, 1976), and has a profile described as representative of the series.

401

Moisture, pH, and other related data for the treated and control plots are presented in Table 123.

SOURCE AND DESCRIPTION OF SLUDGE

Sewage Treatment Plant

The Columbus Treatment and Disposal Plant (STP) provides secondary treatment to wastewaters from a population of 26,500 (1970) and a population equivalent of 50,000 (1976). The plant employs a modified contact stabilization process aided by the use of alum and anionic polymer (Nalco 677) for phosphorus removal. The plant treats an average flow of 24,400 cu m/day (6.45 mgd) with a rated design capacity of 32,400 cu m/day (8.6 mgd). Primary treatment consists of grit removal, pre-aeration, and primary settling. Secondary treatment consists of contact stabilization sludge reaeration and secondary clarification. Sludge is returned from the secondary clarifiers to oxidation, reaeration tanks that operate at 11,000 ppm mixed liquor suspended solids (MLSS) concentration. Return activated sludge from this operation is piped to the contact stabilization mixed liquor tanks operated at a concentration of 2500 to 3000 ppm MLSS.

Effluent from the secondary clarifiers is contact chlorinated prior to discharge to the East Fork of the White River. Secondary treatment efficiencies for the twelve-month period, August, 1975, to July, 1976, are shown in Table 124.

Personnel at the STP estimate that industrial flow constitutes two-thirds of the total plant influent. Table 125 pre-

TABLE 123

CHEMICAL AND PHYSICAL PROPERTIES OF SOILS

COLUMBUS, INDIANA

PLOT / DEPTH	FIELD MOISTURE	ORGANIC CARBON	MECHANICAL ANALYSIS			ORG-N	NO3-N	NH4-N(2)	PH(1)	CEC
			SAND	SILT	CLAY					
	PERCENT					µ G/G				MEQ/ 100GMS
TREATED										
SURFACE	17.9	5.69	54	35	11	0.082	18.4	3.68	6.6	30
30-46 CM	12.3	1.26	52	31	17	0.013	21.0	0.0	7.2	30
46-61 CM	11.5	0.66	62	21	17	0.029	18.1	10.3	6.6	24
61-91 CM	11.2	0.76	68	16	16	0.030	12.7	0.0	7.4	18
91-122 CM	10.4	0.38	73	18	9	0.001	12.8	7.40	7.6	16
CONTROL										
SURFACE	12.5	1.63	22	44	34	0.032	7.30	1.16	6.4	30
30-46 CM	13.3	1.17	34	38	28	0.048	6.20	0.05	6.9	30
46-61 CM	11.8	0.69	47	32	21	0.018	1.40	4.90	7.2	30
61-91 CM	7.0	0.32	70	15	15	0.0	10.1	0.0	6.4	11
91-122 CM	4.5	0.06	90	5	5	0.0	3.70	0.35	6.5	4

(1) 0.01 M CACL2

(2) ORG-N, NO3-N, NH4-N EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 124

COLUMBUS, INDIANA - SECONDARY EFFLUENT TREATMENT EFFICIENCIES

Month	Avg. Daily Flow cu m/day	Influent[1]		Effluent		% Reduction	
		BOD(mg/l)	SS(mg/l)	BOD(mg/l)	SS(mg/l)	BOD	SS
Aug. 1975	27668	145	241	4	10	97.2	95.9
Sept.	23808	149	217	3	5	98.0	97.7
Oct.	24035	164	230	4	6	97.6	97.4
Nov.	25549	177	177	6	8	96.6	95.5
Dec.	21310	161	229	7	11	95.7	95.2
Jan. 1976	24527	157	210	8	10	94.9	95.2
Feb.	24527	161	210	7	9	95.7	95.7
Mar.	25549	160	256	10	16	90.7	93.7
Apr.	21802	178	219	9	13	94.9	94.1
May	22445	162	207	6	8	96.3	96.1
June	24565	143	211	4	6	97.2	97.4
July	27252	151	242	8	12	94.7	95.0
Aug.	24420	159	221	6.3	9.5	95.8	95.7

TABLE 125

INDUSTRIAL DISCHARGE PARAMETERS[1]
SUMMARY - APRIL-JUNE 1976

					Concentrations - mg/l				
Processor	Product	Flow (cu m/day)	pH	BOD 5 day	SS	Pb	Zn	Cu	Ni
Cosco	Plater	208	-	-	-	-	-	-	2.9
National Linen	Laundry	136	10.4	637	502	1.75	1.95	0.79	-
Waldorf	Cardboard	98	-	170	424	21.30	0.54	-	-
Stadler[2] Packing	Meat Packing	3785	-	24.5	39	Insignificant Levels			
Saps	Baking	356	-	4088	3800	0.12	1.81	-	-
Golden Foundry	Castings	5678	-	848	Insignificant Levels				
Cummins C-P	Diesel Eng.	257	8.6	149	220	-	-	-	-
Cummins Walesboro[3]	Diesel Eng.	990	8.0	379	557	-	1.68	-	-
Arvin Ind.	Furniture	519	-	-	-	Insignificant Levels			
Reliance	Electric	689	-	-	-	Insignificant Levels			

[1] Columbus STP data.

[2] Discharges-treated effluent to secondary treatment of STP.

[3] Pretreats - effluent values.

sents a 3-month summary of analytical and flow data for the major industrial contributors.

It is interesting to note that pretreated effluent from the Stadler Packing Plant is piped directly to the aeration tanks, conserving primary clarifier capacity in the plant. Pretreatment at the Stadler plant is provided by three lagoons; the first two are anaerobic, add the third is a facultative stabilization and holding pond. Anaerobiosis is assured in the first two lagoons by a layer of tallow intentionally spread over the surfaces to provide an air seal. Detention time of the ponds is approximately 5 to 7 days.

Sludge Stabilization and Storage

Sludge stabilization is accomplished in one of two parallel, connected 2260 cu m (0.6 mg) anaerobic digesters. Combined detention time is approximately 30 days. Sludge from the primary clarifiers is pumped directly to the digesters. Withdrawal for land spreading is directly from one of the digestion tanks.

Ten drying beds were available for additional storage capacity prior to 1976, but these have been removed as a part of a major STP expansion program.

The sludge is routinely analyzed by the STP with standard atomic absorption (AA) techniques. An additional sample was taken during Phase I of this study (Sept. 19, 1975) and was analyzed with similar AA techniques. Table 126 presents these analytical data. Metal concentrations appear to be uniformly low and do not exhibit significant fluctuation over time.

TABLE 126

COLUMBUS, INDIANA - LIQUID STABILIZED SLUDGE ANALYSES

Date[1]	pH	Concentration (μg/g) - Wet Weight Basis					
		Cd	Cu	Ni	Zn	Pb	Cr
1/6/76	6.8	0.52	21.2	31.5	65	37	20.8
1/22/76	-	1.12	30.8	45	88	35	44
1/30/76	6.9	1.16	23.4	24	97.5	14	22.6
2/12/76	7.1	1.4	23.1	23	67.5	28.5	28.8
1/13/76	-	2.0	25.2	41.6	-	31.4	39.6
3/3/76	-	0.21	19.0	14.2	44	23.2	44
3/11/76	5.8	1.0	23.8	18	84	27.2	41
3/25/76	-	0.56	18.8	13.6	37	19.2	22.6
4/6/76	5.9	0.58	18.8	12.6	42.5	22	29.4
4/13/76	6.3	0.67	22	14.8	69.7	23.6	34.6
4/20/76	6.9	0.8	27.4	17	53.6	27	38.6
4/27/76	6.8	0.74	26	14.4	54.8	22	36.8
5/6/76	-	0.68	18.8	18.4	52	20	22.4
5/26/76	7.2	5.0	18	68	52.4	15	21.2
6/3/76	7.1	0.56	22.4	13.4	60.8	17.2	38
6/10/76	7.0	0.6	25.4	16.6	61.6	61.6	36.8
Date[2] 9/19/75		0.42	12.0	26.7	54.0	18.9	-
		(12.4)	(353)	(785)	(1590)	(555)	-

[1] Columbus, Indiana STP analysis

[2] Phase I stabilized sludge sample, September 19, 1975. Concentrations in parentheses are expressed on an oven weight basis.

Disposal of Sewage Sludge

The STP has been landspreading sludge since 1965. Sludge generated during the 12-month period from July, 1975, to June, 1976, totaled 43,546 cu m (11.5 MG). Table 127 shows the monthly distribution and amounts of dry sludge generated. These figures are based on an average solids content of 5 percent as reported from STP analyses.

The treated field received heavy applications of sludge from 1971 to 1975, as shown in Table 128 This land was leased by the city to serve as a "disposal" ground for a large percentage of its sludge. Though the study site will probably no longer be used for this purpose, the STP has and continues to land spread sludge at several other local sites totaling about 81 ha (200 acres). The city does not pay for the use of this other acreage.

Until 1976, sludge at the treated field was distributed by either flooding through a 10.2 cm (4 in) irrigation pipe (88 percent of the total sludge applied) or by tank truck (12 percent). Truck spreading between 1965 and 1975 was accomplished with a 1965 Dodge truck fitted with a 9.1 cu m (2400 gal) tank. In 1975, a new Marman truck with a 9.8 cu m (2600 gal) tank was purchased. In the summer of 1976, a third vehicle - a Simpson Big Wheels - with a 4.5 cu m (1200 gal) tank was purchased.

Sludge is generally spread on a year-round basis and has been accomplished since 1975 exclusively with tank trucks. Once loaded, the trucks drive to the field and, traveling at a

TABLE 127

COLUMBUS, INDIANA - SLUDGE GENERATION

Month	Liquid Sludge Generated (cu m)	Dry Sludge[1] Generated (m tons)
Jul. 1975	3727	186
Aug.	3615	181
Sept.	3683	184
Oct.	3940	197
Nov.	3225	161
Dec.	3345	167
Jan. 1976	3793	190
Feb.	2971	148
Mar.	3940	197
Apr.	3787	189
May	3701	185
Jun.	3824	191
TOTAL	43551	2174

[1] Sludge @ 5 percent solids (STP data).

409

TABLE 128

COLUMBUS, INDIANA – SLUDGE APPLICATION RATES

Year	Total Dry Sludge Applied (metric tons)	Application Rate (metric tons/ha)[1]
1971	523	37
1972	1,625	115
1973	1,285	91
1974	945	67
1975	227	16

---

[1] Based on 5 percent sludge solids (STP data).

410

steady speed, distribute their loads by gravity through a fan spreader. Each load is spread over an area approximately 300 m (1000 ft) long and 2 m (6 ft) wide. Photographs 37 through 39, respectively, show the treated field, tank truck depositing sludge, and the sludge saturated ground.

Interviews with various STP personnel and the farmer of the treated field indicate no apparent environmental problems. When questioned regarding the use of his property as a disposal site, the farmer stated that he probably would accept additional sludge only if applied in a manner to assure him that no possible deleterious effects on his crops would occur.

PUBLIC ATTITUDES TOWARD LANDSPREADING OF SLUDGE

Interviews were conducted with personnel from the local newspaper, The Republic, and with the head of the Bartholomew Department of County Health. Employees at The Republic indicated that they had never printed any article pertaining to any aspect of sewage sludge disposal. The head of the Bartholomew County Department of Health was aware of the sludge spreading parctice and thought it to be an acceptable disposal alternative. He has had no involvement with the program and stated that he was not aware of any health problems associated with sludge handling.

The resident soil conservationist from the Soil Conservation Service was aware of the sludge spreading practice. He also was not cognizant of any problems associated with land spreading of sludge.

Photograph 37

Treated Field

LIQUID FERTILIZER

Photograph 38

Tank Truck Depositing Sludge

Photograph 39

Sludge Saturated Ground

413

STATE AND LOCAL REGULATIONS ON SLUDGE SPREADING

Interviews with various personnel from the STP indicate that permits have not been required for any aspect of the sludge-spreading program. Inoculations for polio, typhoid, and tetanus are given to all the STP employees. The Columbus Health Department regulates and records the inoculations for each employee.

ECONOMICS

The STP has maintained monthly records of their sludge-spreading costs since the inception of the program in 1965. Capital equipment purchased for the period 1965 to June, 1976, are shown in Table 129.

During the four years when the STP used the study site for sludge disposal, the 14.2 ha (35 acre) field was rented at $4,000/year. The annual rental fee was increased to $5,000 starting in 1975.

Detailed cost records supplied by the STP covering the period from July, 1975 to June, 1976, are presented in Table 130. Table 131 presents a cost analysis of the sludge-spreading operation.

SAMPLING AND ANALYSIS

Sludge

On July 13 and November 29, 1976, five one-liter grab samples each of raw and stabilized sludge were obtained from both the primary clarifiers and the anaerobic digester.

TABLE 129

COLUMBUS, INDIANA - CAPITAL EXPENDITURES

Year Purchased	Description	Cost
1965	1965 Dodge Truck	$ 8,000
1965	9.1 cu m (2400 gal) Tank	600
1971	Irrigation Pipe	1,700
1971	Irrigation Pump	1,116
1975	1975 Marmon Truck	30,000
1975	9.8 cu m (2600 gal) Tank	1,440

TABLE 130

COLUMBUS, INDIANA - LIQUID SLUDGE SPREADING COSTS

Month	Total Wages	Maintenance	Fuel
July 1975	$1420	$254	$327
Aug	1204	270	177
Sept	1125	455	321
Oct	1227	890	326
Nov	1222	950	212
Dec	1276	59	374
Jan 1976	1369	330	386
Feb	1245	517	263
Mar	1533	278	387
Apr	1567	314	333
May	1519	214	330
June	1574	447	376
Total	$16281	$4978	$3812

416

TABLE 131

COST FOR DISPOSAL OF LIQUID SLUDGE
JULY, 1975 - JUNE, 1976

Annual Capital Cost	
Vehicle Depreciation[1] 1975 Marman Truck cost: $3,000 1975 9.8 cu m Tank cost: $1,440	$5,335
Stationary Equipment Depreciation[2] 1971 Irrigation Pipe cost: $1,700 1971 Irrigation Pump cost: $1,116	410
Total Annual Capital Cost	$5,745
Annual Operating Cost	
Personnel (see Table IX-9)	$16,281
Fringe Benefits (25 percent)	4,070
Vehicle Maintenance and Operation	4,978
Fuel Costs	3,812
Total Annual Operating Cost	$29,141
Total Annual Capital and Operating Cost	$34,886
10 Percent Contingency Factor[3]	3,489
Total Annual Cost	$38,375

$$\frac{\text{Total Annual Cost}}{\text{Total Sludge Hauled Annually}} = \frac{\$38,375}{2396 \text{ dry tons}^{4}} = \frac{\$17.65/\text{dry m ton}}{(\$16.02/\text{dry ton})}$$

---

[1] Vehicles were fully depreciated over 8 years assuming 8 percent interest, equivalent to $169.68 per $1,000 annually.

[2] Stationary equipment was fully depreciated over 10 years assuming 8 percent interest, equivalent to $145.56 per $1,000 annually.

[3] A 10 percent contingency factor is added to cover such items as administrative overhead.

[4] Based on 5 percent solids (STP analytical data).

Soil

On July 13 and 14, 1976, surface soil samples were taken from both the treated and the original control plots. Both plots were divided into five sections. A 2.5 cm (1 in) diameter stainless steel split tube sampler was used for all samplings. Approximately 30 individual cores were obtained from the surface 0 to 30 cm (0 to 12 in) of soil. Sample corings from the control field were taken "on line" - i.e., corings were obtained every 5 m (15 ft) along one row of corn. The technicians then crossed to the third parallel row and removed additional individual cores every 5 m (15 ft), while returning to the starting point of that section. Any miscellaneous, non-soil debris was removed from the sample device prior to depositing of all individual cores into their respective sample bags.

Subsurface samples were obtained with an 8 cm (3 in) diameter stainless bucket auger. Sampling at the treated plot was accomplished by obtaining cores to 122 cm (48 in) from four approximately equally spaced areas within each section. Samples from the control plot were obtained by four corings to 122 cm (48 in) along one row of corn for each section. Samples from both plots taken from the 30 to 46 cm (12 to 18 in) layers were labeled horizon A; those from 46 to 61 cm (18 to 24 in) level as horizon B; 61 to 91 cm (24 to 36 in) horizon C; and 92 to 122 cm (36 to 48 in) horizon D.

As noted in Soil Description, sand at the 61 m (2 ft) level was encountered in the control plot along the Section 1 line.

Sampling at the D horizon on the control plot was difficult due to a combination of pebbles and large sand.

Plants

On July 13 and 14, 1976, corn leaf samples were obtained from both the treated and original control plots. The uppermost mature leaf on the plant was selected for sampling. Corn on both plots was in vigorous growth with small ears from 5 to 8 cm (2 to 3 in) appearing on most stalks. Sampling techniques were similar to those for soils. Leaves from the treated plot were obtained within the area of each section; and leaves from the control plot were obtained by walking the section line, gathering one leaf every 5 m (15 ft) on the return to the starting point (head of the field). Thirty (30) leaves were taken to represent each section from each plot.

On October 25, 1976, mature and field-dried ears of corn were sampled from both the treated plot and "second" control plot. Thirty ears of corn representing the area within each section of the treated plot were obtained, resulting in a 150-ear sample for the entire plot. One hundred (100) random ears were selected as a field composite to represent the control plot.

Upon arrival in Long Beach, California, each ear was broken in half, and approximately five rows of kernels around the diameter at the break removed to represent the ear. Those kernels were placed in new plastic bags marked to represent the individual sections. Master field composites were made necessary prior to the transfer of all samples to the laboratory.

417

Tables 132 through 139 present the following:

Table	Description
132	Chemical Characterization of Stabilized Sludges
133	Concentrations of Total and DTPA Extractable Metals in Composite Surface and Subsurface Soils
134	Total Metal Concentrations in Individual Subsurface Soil Samples
135	Metal Concentrations in Surface Soils and Plants
136	Metal Concentrations in Corn Grain Samples
137	Chlorinated Hydrocarbon Concentrations in Sludge, Soils, and Plants
138	Parasites in Sludges, Soils, and Plants
139	Concentrations of Microbes in Sludges, Soils, and Plants

Figures 98 to 107 present particle size analyses of the various soil composites by depth.

TABLE 132

CHEMICAL CHARACTERIZATION OF STABILIZED SLUDGES FROM COLUMBUS, INDIANA

	7/13/76	11/29/76	Average
Volatile Solids (%)	55.18	54.84	55.0
NO_3 - N	n.d.	12.0	6
NH_4 - N	9487	15933	12710
Organic N	11106	34970	23038
P	11936	14699	13317
K	1745	4608	3177
Na	4213	8012	6113
Ca	17532	27680	22606
Mg	3362	8343	5853
SO_4	47.9	188	118
Cl	2872	3524	3198
Ag	1.28	1.81	1.23
As	1.06	3.31	2.19
B	27.4	50.0	38.7
Cd	4.47	6.93	5.7
Cr	355	473	414
Co	25.5	22.6	24.1
Cu	315	470	393
Fe	8553	11747	10150
Hg	3.09	2.11	2.6
Mn	394	551	473
Mo	34.7	7.53	21.1
Ni	138	184	161
Pb	179	24.1	102
Se	0.28	13.0	6.64
Zn	574	898	736
H_2O (%)	95.3	96.7	96.0
pH	8.2	7.8	

All units in μg/g (unless otherwise noted).

All data expressed on oven dry weight basis.

TABLE 133

CONCENTRATIONS OF TOTAL AND DTPA EXTRACTABLE METALS IN COMPOSITE SURFACE AND SUBSURFACE SOILS (1)

COLUMBUS, INDIANA

PLOT/ DEPTH:	TOTAL METALS (2) CD	CU	NI	ZN	PB	DTPA EXTRACTABLES CD	CU	NI	ZN
	µG/G					µG/G			
TREATED									
SURFACE	4.37	185	521	625	190	0.74	21.4	60.4	59.1
30-46 CM.	0.39	19.7	41.1	70.0	24.9	0.22	2.25	2.67	2.02
46-61 CM.	0.41	17.9	31.9	57.0	16.4	0.17	1.44	1.51	1.54
61-91 CM.	1.46	21.7	38.4	57.0	21.6	0.13	1.84	2.65	1.79
91-122 CM.	1.75	19.4	42.0	51.3	51.0	0.20	1.64	2.72	2.11
CONTROL									
SURFACE	0.78	20.3	30.0	80.6	21.9	0.19	2.58	1.73	1.94
30-46 CM.	0.49	18.8	34.5	75.0	19.8	0.14	1.90	1.46	0.80
46-61 CM.	0.49	15.7	32.4	61.7	15.8	0.13	1.55	1.20	0.84
61-91 CM.	1.57	9.65	32.8	35.5	19.5	0.12	0.70	0.93	0.49
91-122 CM.	2.00	5.91	32.1	22.3	22.6	0.10	0.40	0.69	0.42

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

(2) HNO3-HCLO4 DIGESTION.

TABLE 134

TOTAL METAL CONCENTRATIONS IN INDIVIDUAL SUBSURFACE SOIL SAMPLES (1)

COLUMBUS, INDIANA

SECTION/ DEPTH	TREATED CD	TREATED CU	TREATED NI	TREATED ZN	CONTROL CD	CONTROL CU	CONTROL NI	CONTROL ZN
	µG/G				µG/G			
SECTION 1								
30-46 CM.	0.24	16.5	28.0	56.1	0.57	16.4	31.1	69.7
46-61 CM.	0.45	17.8	30.0	57.4	0.41	14.9	28.1	54.6
61-91 CM.	0.89	16.7	31.2	50.3	2.06	9.25	34.2	28.2
91-122 CM.	1.61	14.7	39.1	40.7	1.70	8.81	34.0	21.5
SECTION 2								
30-46 CM.	0.66	22.6	41.0	74.7	0.68	19.0	33.2	77.0
46-61 CM.	0.61	18.6	37.4	68.1	0.37	15.3	28.8	59.3
61-91 CM.	1.34	32.8	65.1	81.8	1.77	12.1	35.0	37.0
91-122 CM.	1.77	17.5	41.3	48.9	1.81	7.32	31.7	25.6
SECTION 3								
30-46 CM.	0.49	19.7	44.0	76.7	0.68	19.5	35.0	79.8
46-61 CM.	0.37	15.9	29.9	53.4	0.57	17.6	32.0	65.7
61-91 CM.	0.36	18.3	32.4	54.1	0.74	9.36	25.6	32.2
91-122 CM.	1.13	17.5	36.3	43.6	1.56	7.62	30.1	23.6
SECTION 4								
30-46 CM.	0.39	21.6	41.0	71.2	0.60	29.8	34.7	79.0
46-61 CM.	0.24	17.3	35.7	60.0	0.65	15.5	31.6	58.3
61-91 CM.	0.71	16.8	30.6	46.1	1.69	9.75	31.5	30.7
91-122 CM.	0.99	14.8	39.1	43.6	1.82	6.11	33.3	21.0
SECTION 5								
30-46 CM.	0.39	19.1	36.1	61.6	0.78	19.1	34.1	76.8
46-61 CM.	0.37	16.3	30.4	50.2	0.41	18.3	36.1	73.9
61-91 CM.	0.59	16.7	32.2	39.2	1.42	13.3	37.5	51.8
91-122 CM.	1.00	18.1	35.4	38.8	2.10	6.31	36.2	24.3

(1) HNO3-HCLO4 DIGESTION; ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.

TABLE 135

METAL CONCENTRATIONS IN SURFACE SOILS AND PLANTS[1]

COLUMBUS, INDIANA

SAMPLE	SURFACE SOIL CD	CU	NI	ZN	PB[2]	PLANT CD	CU	NI	ZN	PB[2]	ORG-N[2]
	μG/G					μG/G					
TREATED											
COMPOSITE	4.37	185	521	625	190	2.49	11.8	9.13	53.8	2.98	3.13
SECTION 1	2.89	143	432	503		2.01	11.5	10.80	61.7		
SECTION 2	3.05	164	546	531		2.25	11.7	9.52	63.9		
SECTION 3	4.15	180	553	640		2.35	12.2	9.81	61.7		
SECTION 4	4.01	170	528	585		1.68	12.4	7.79	44.2		
SECTION 5	3.52	152	421	519		3.27	13.5	8.17	63.4		
MEAN	3.52	162	496	556		2.31	12.3	9.22	59.0		
STD. DEV.	0.56	14.6	64.2	56.35		0.59	0.78	1.23	8.32		
CONTROL											
COMPOSITE	0.78	20.3	30.0	80.6	21.9	1.25	9.81	5.67	38.9	2.93	2.96
SECTION 1	0.66	20.1	29.8	78.1		1.25	12.1	6.15	45.9		
SECTION 2	0.65	20.1	29.5	78.9		2.09	11.4	5.58	42.9		
SECTION 3	0.85	19.5	31.9	83.8		1.32	10.6	6.41	39.6		
SECTION 4	0.66	20.3	32.1	86.3		1.20	10.3	5.19	38.1		
SECTION 5	0.69	17.5	30.0	82.1		1.27	9.93	5.58	33.7		
MEAN	0.70	19.5	30.7	81.8		1.43	10.9	5.78	40.0		
STD. DEV.	0.08	1.16	1.24	3.41		0.37	0.88	0.49	4.65		

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.

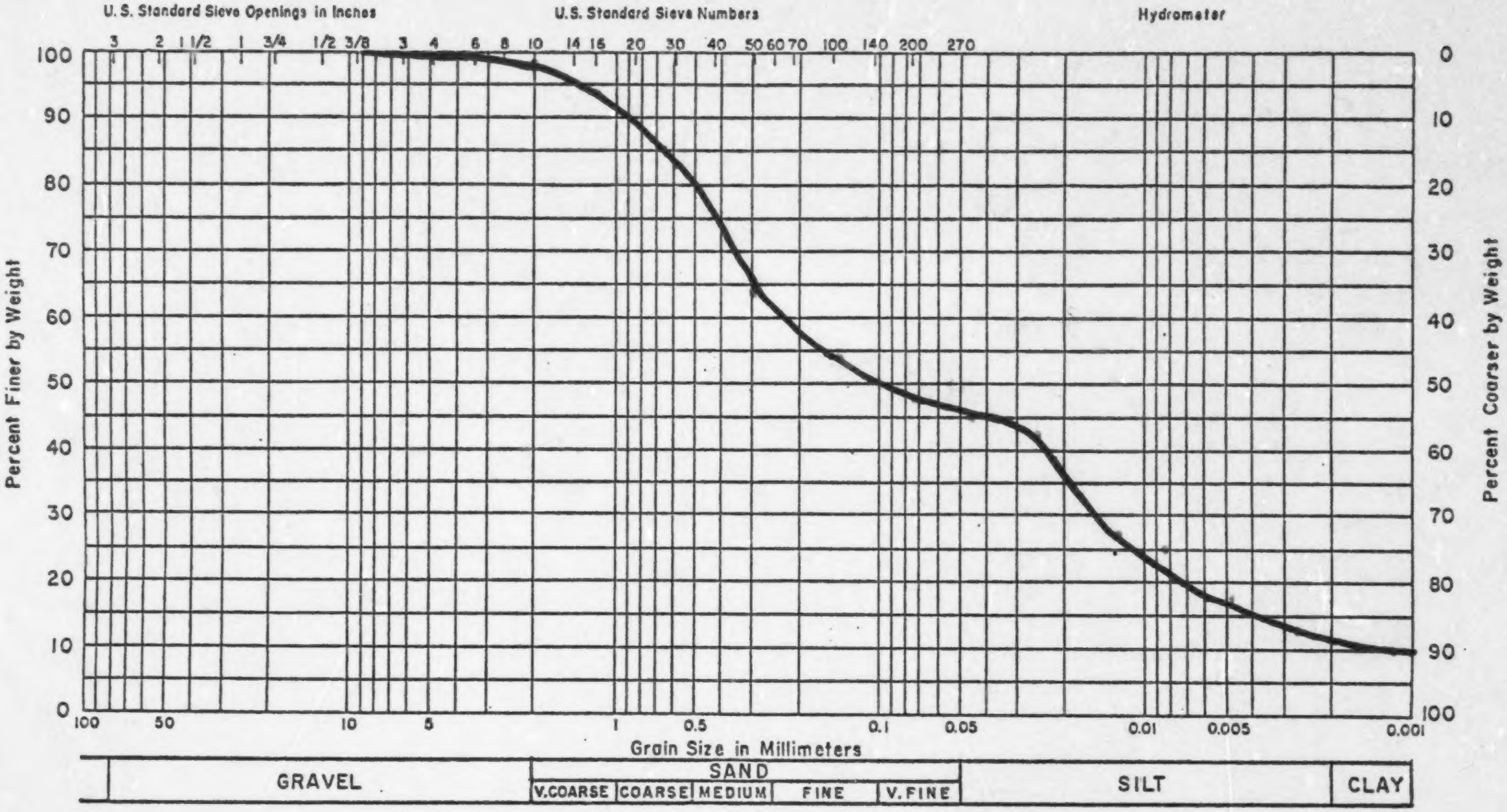
TABLE 136

METAL CONCENTRATIONS IN CORN GRAIN SAMPLES(1)

COLUMBUS, INDIANA

SAMPLE			PLANT			
	CD	CU	NI	ZN	PB(2)	ORG-N(2)
			µG/G			
TREATED						
COMPOSITE	0.67	2.57	4.01	24.7	1.34	1.70
SECTION 1	0.23	2.33	4.90	27.5		
SECTION 2	0.52	2.19	6.29	29.7		
SECTION 3	0.42	3.05	5.66	34.0		
SECTION 4	0.48	1.62	3.77	27.4		
SECTION 5	0.48	2.62	4.03	27.4		
MEAN	0.43	2.36	4.93	29.2		
STD. DEV.	0.12	0.53	1.07	2.86		
CONTROL						
COMPOSITE	0.26	2.58	6.64	29.8	1.40	1.20
SECTION 1						
SECTION 2						
SECTION 3						
SECTION 4						
SECTION 5						
MEAN						
STD. DEV.						

(1) ALL DATA EXPRESSED ON OVEN DRY WEIGHT BASIS.
(2) ANALYSIS ON COMPOSITE ONLY.



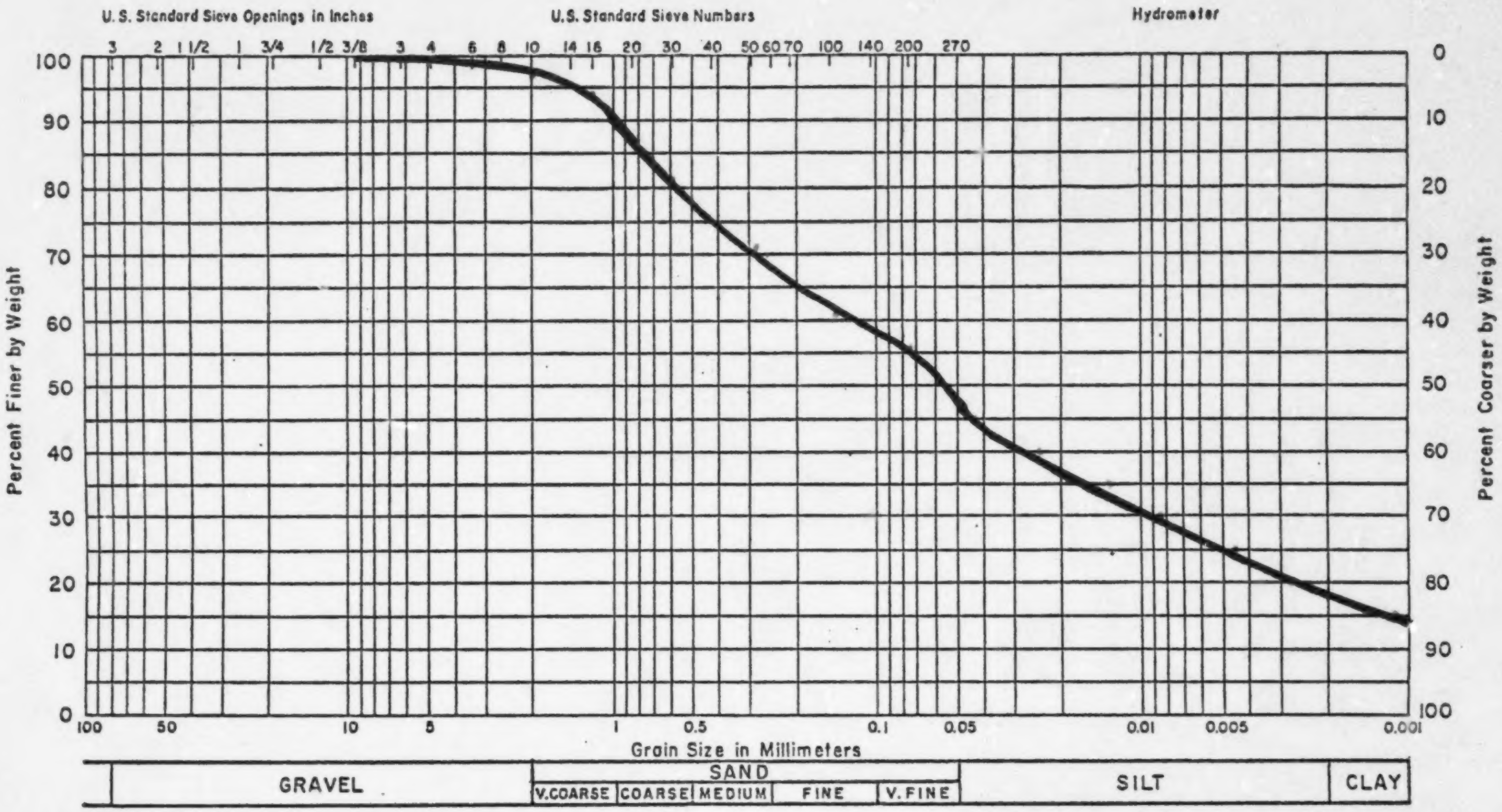
SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1165	Columbus	54	35	11	Sandy Loam
	Treated				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90207

Figure 98 Columbus, IN, Particle Size Analysis

All fig's same title

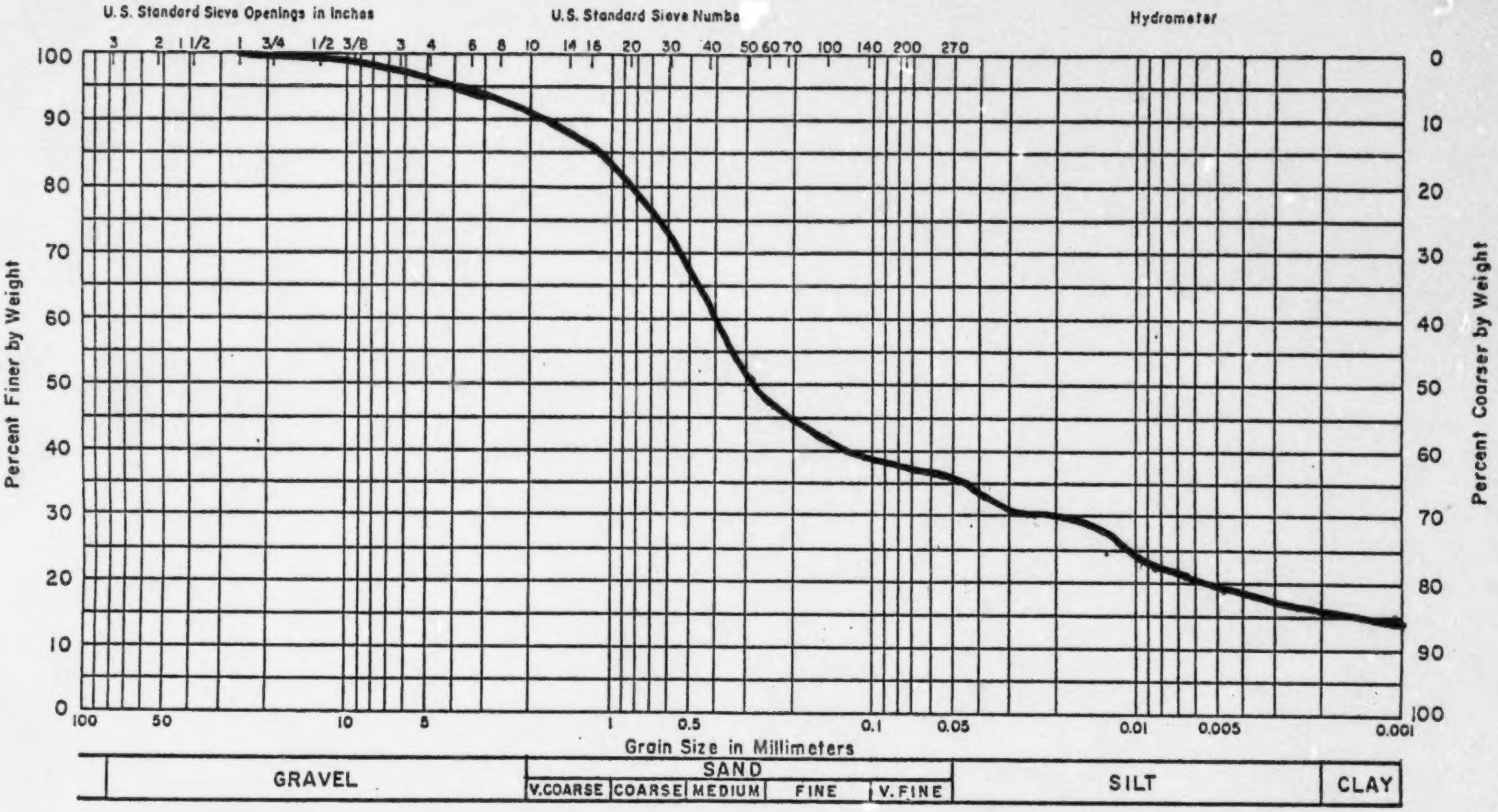
Figure 98 Columbus, Indiana Particle Size analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1171	Columbus	52	31	17	Loam/Sandy Loam
	Treated				
	30-46 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

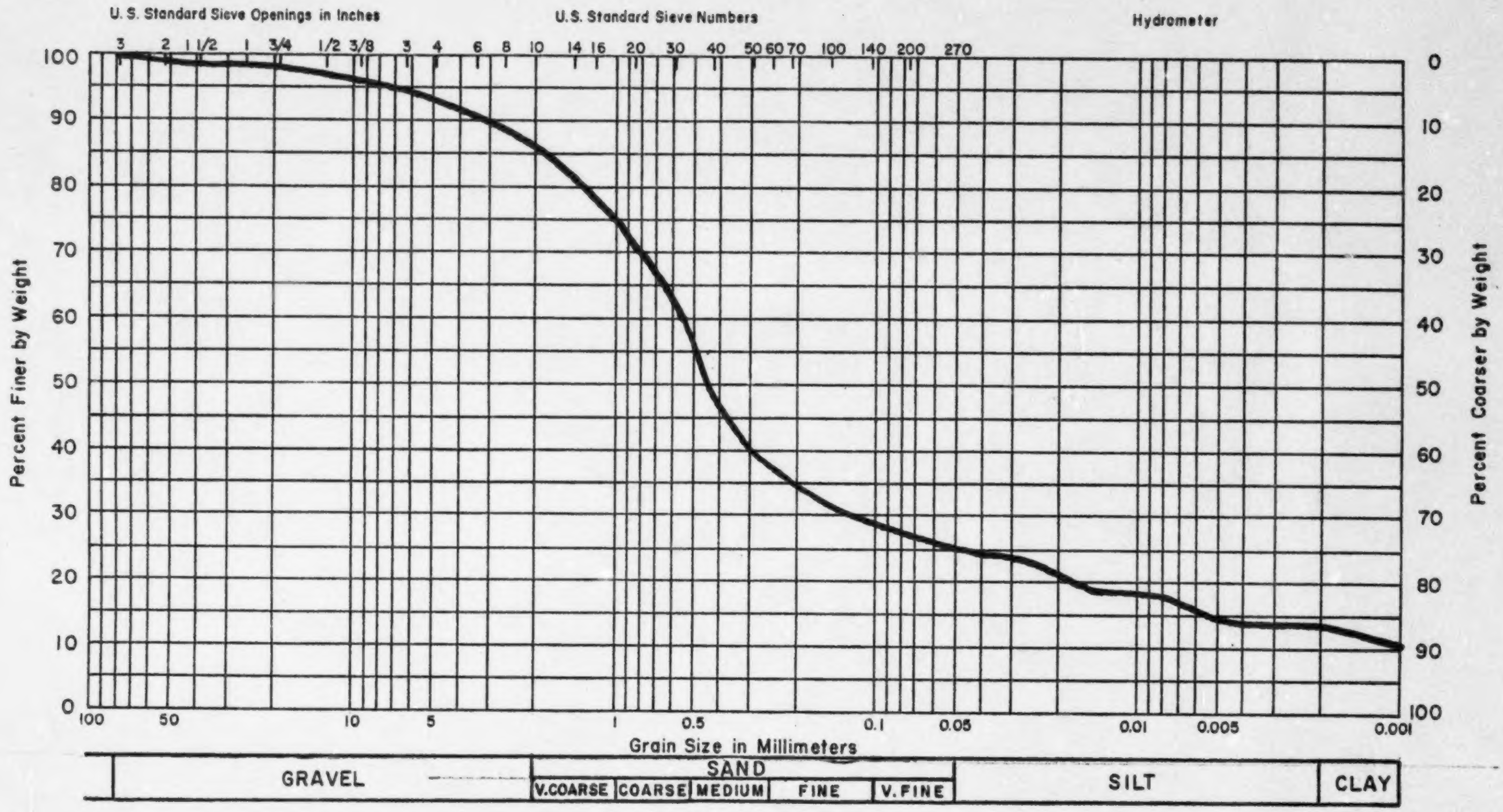
Figure 99 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1177	Columbus	62	21	17	Sandy Loam
	Treated				
	46-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

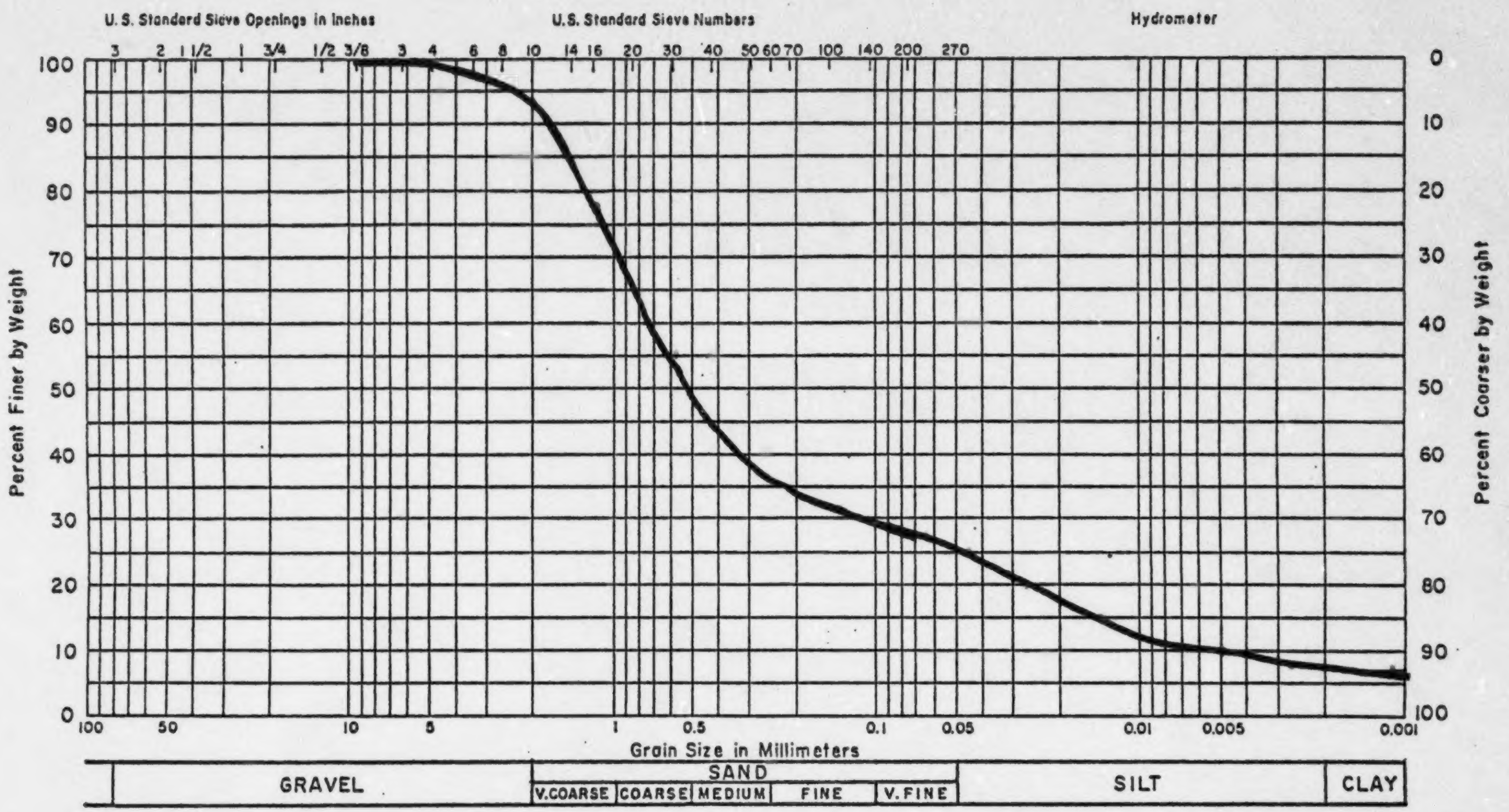
Figure 100 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1183	Columbus	68	16	16	Sandy Loam
	Treated				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

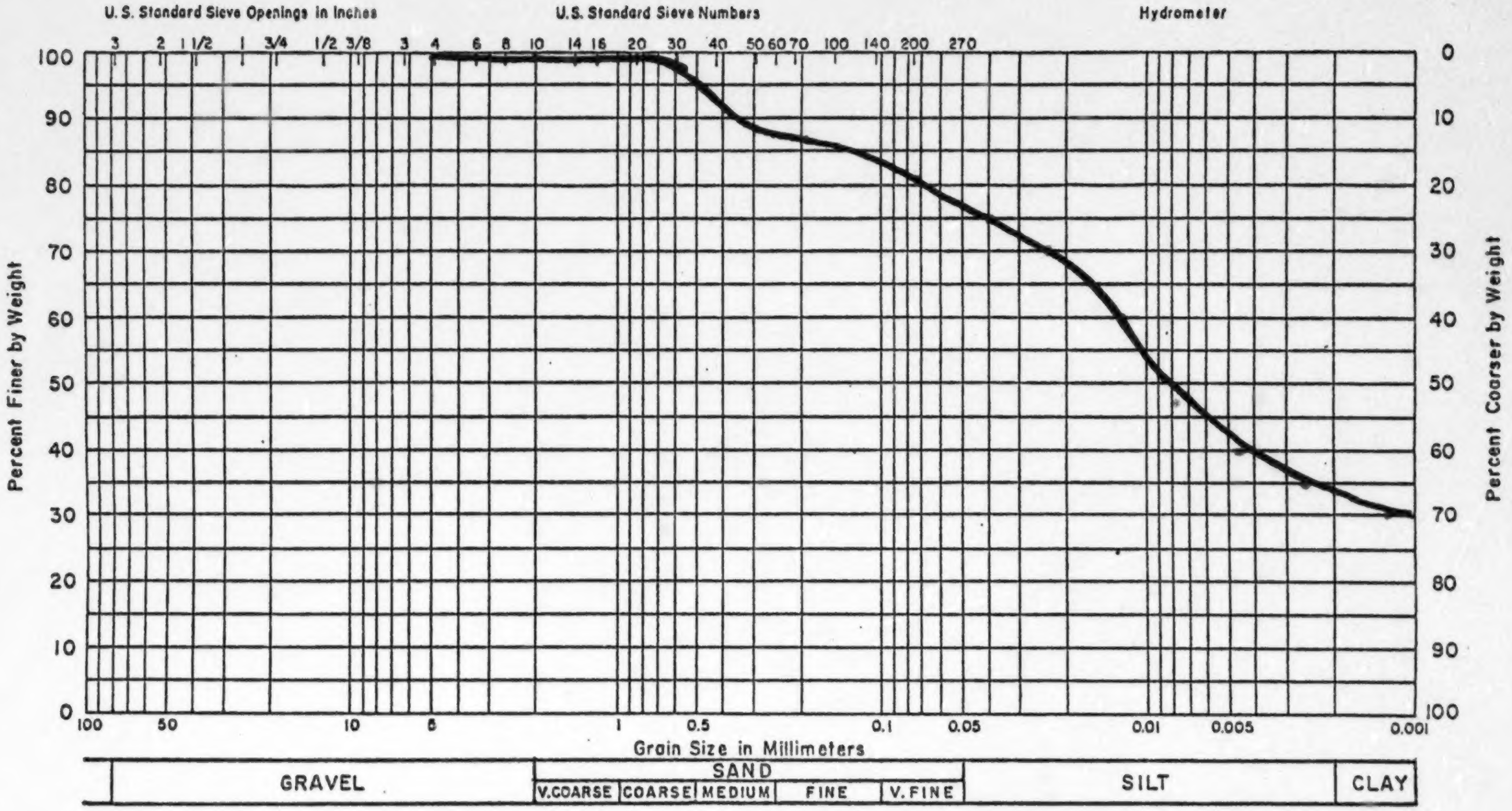
Figure 101 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1189	Columbus	73	18	9	Sandy Loam
	Treated				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 102 Columbus, IN, Particle Size Analysis

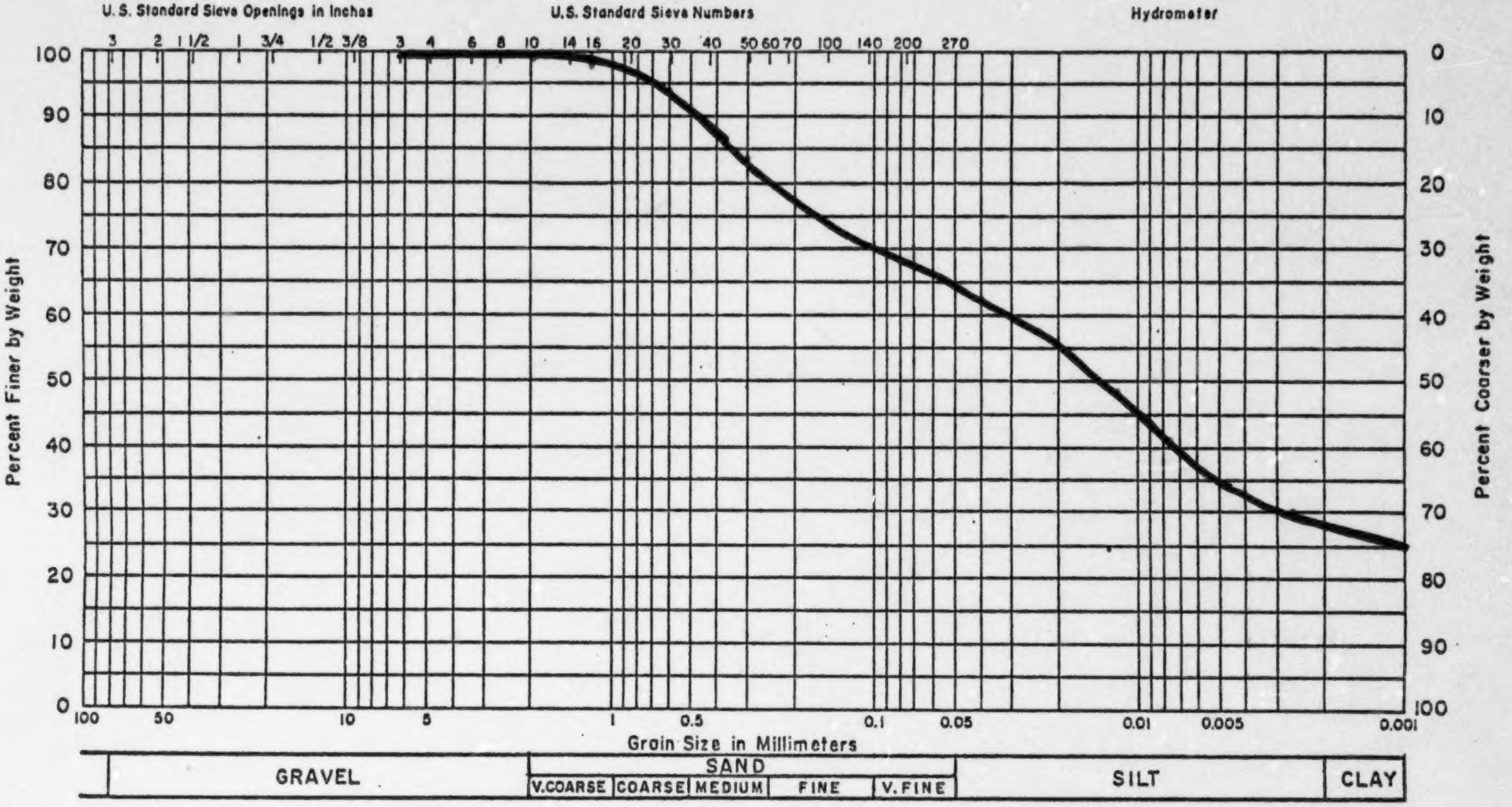


SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1135	Columbus	22	44	34	Clay Loam
	Control				
	Surface				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 103 Columbus, IN, Particle Size Analysis

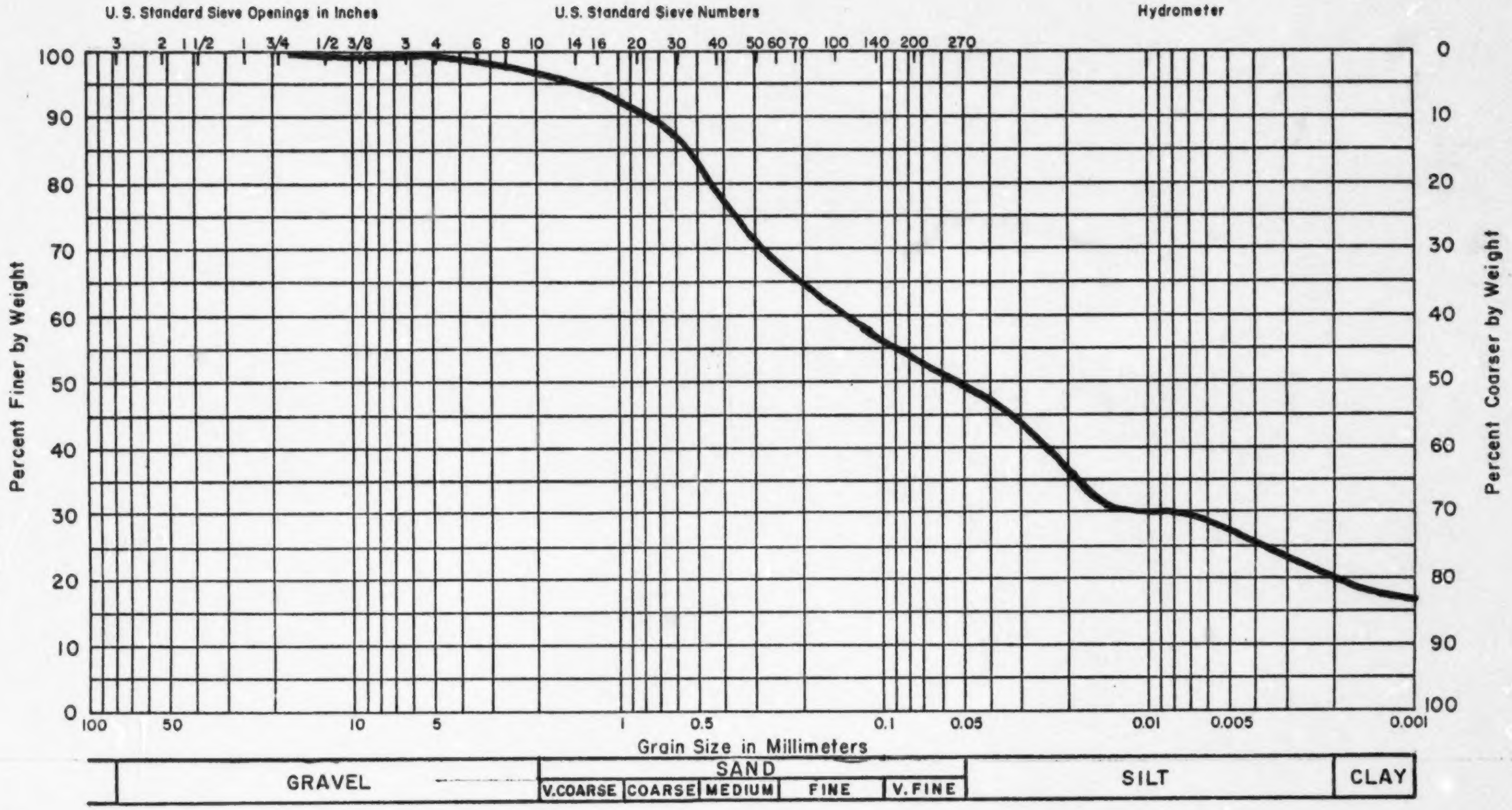
IX-8



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1141	Columbus Control 30-46 cm	34	38	28	Clay Loam

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

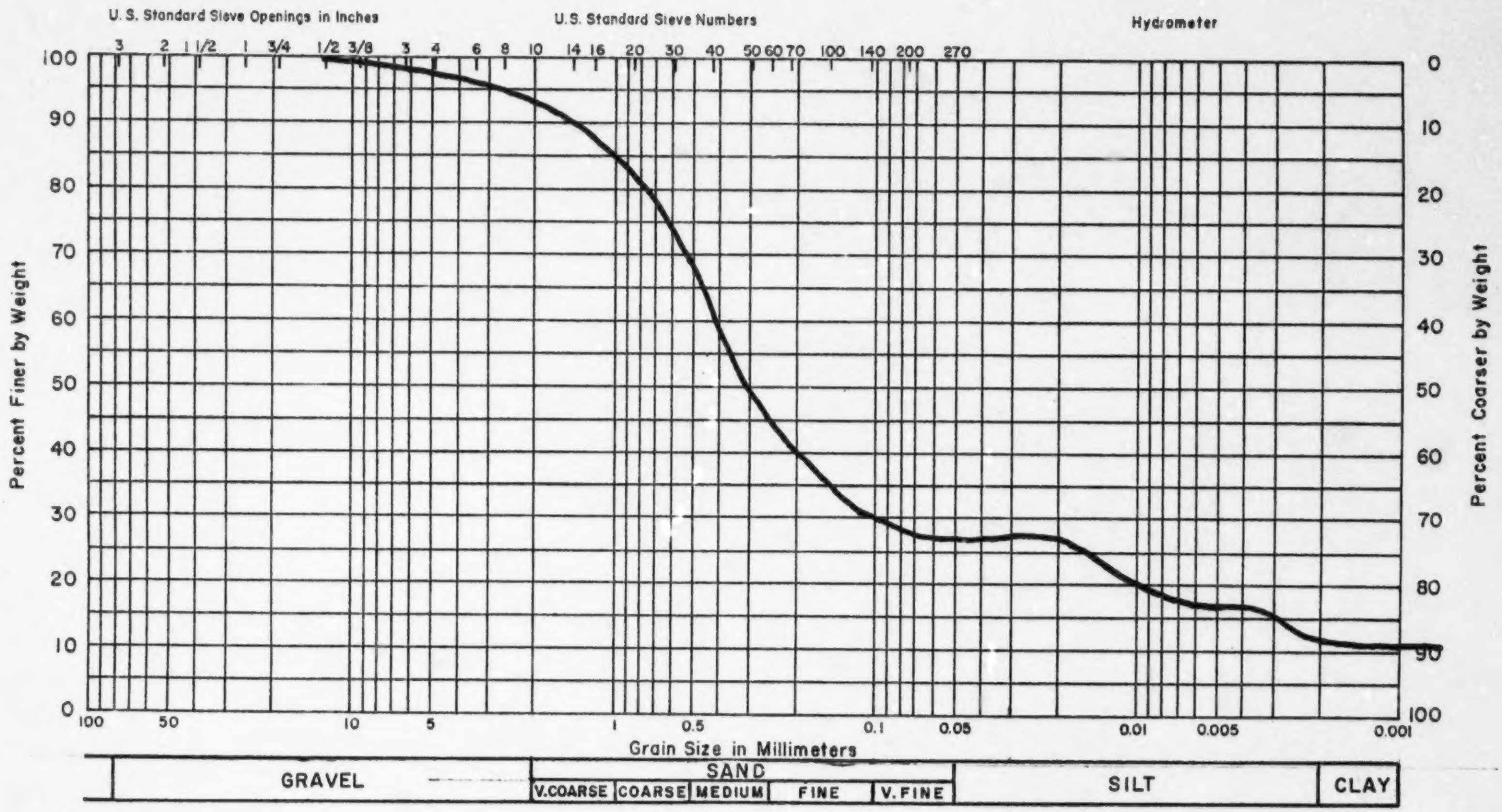
Figure 104 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1147	Columbus	47	32	21	Loam
	Control				
	46-61 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

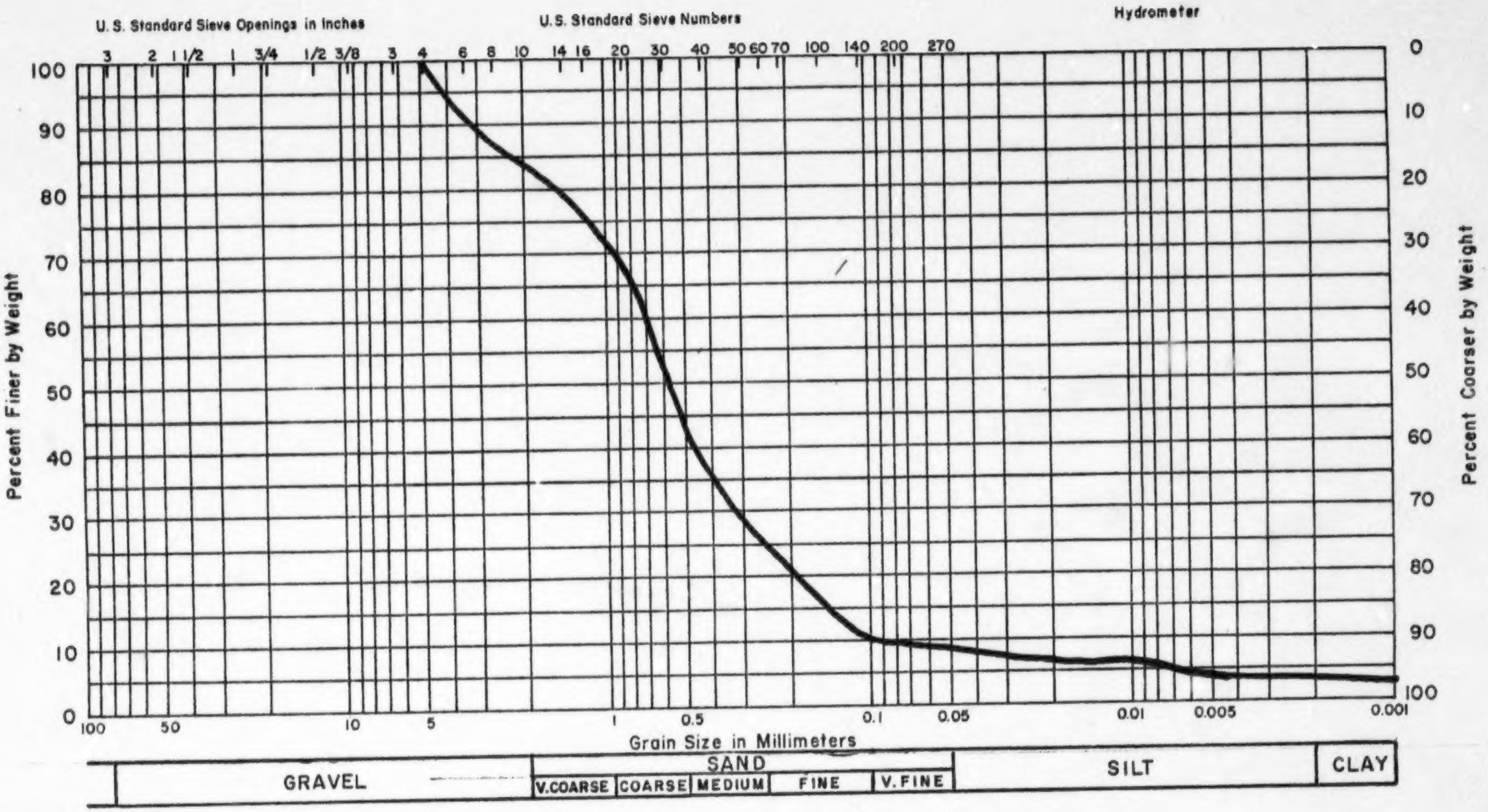
Figure 105 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1153	Columbus	70	15	15	Sandy Loam
	Control				
	61-91 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 106 Columbus, IN, Particle Size Analysis



SAMPLE NO.	DESCRIPTION	% SAND	% SILT	% CLAY	CLASSIFICATION
1159	Columbus	90	5	5	Sand
	Control				
	91-122 cm				

SCS ENGINEERS
STEARNS, CONRAD AND SCHMIDT
CONSULTING ENGINEERS, INC.
TEL: 213/426-9544
4014 LONG BEACH BOULEVARD, LONG BEACH, CALIFORNIA 90807

Figure 107 Columbus, IN, Particle Size Analysis

TABLE 137

CHLORINATED HYDROCARBON CONCENTRATIONS IN SLUDGE, SOILS AND PLANTS

COLUMBUS, INDIANA

	Treated Plot	Control Plot	Chlorinated Hydrocarbon
	. . . . µg/kg	. . . .	
Soil			
Surface Composites	0.13	<0.01[1]	DDT
	<0.01	<0.01	DIELDRIN
	<0.5	<0.5	PCB 1221
	216	<0.4	PCB 1248
Plant			
Composites	<0.02	<0.02	DDT
	<0.01	<0.01	DIELDRIN
	<0.25	<0.75	PCB 1221
	<0.75	<0.5	PCB 1248
Grain			
Composites	<0.001	<0.004	DDT
	<0.001	<0.0024	DIELDRIN
	<0.1	<0.1	PCB 1221
	<0.1	<0.1	PCB 1248
	(7/13/76)	(11/29/76)	
Stabilized Sludge	<0.4	0.9	DDT
	<0.04	<0.18	DIELDRIN
	<0.4	<0.1	PCB 1221
	<15	<27	PCB 1248

---

[1] Detection limits vary due to sample size, plant matter interference, and instrument sensitivity.

TABLE 138

PARASITES IN SLUDGES, SOILS, AND PLANTS

COLUMBUS, INDIANA

Sample Description	Results
Sludge	
Raw (7/13/76)	Negative
Raw (11/29/76)	Negative
Stabilized (7/13/76)	Negative
Stabilized (11/29/76)	Negative
Plants	
Treated - leaf	Negative
Control - leaf	Negative
Soils - Treated Composites	
Surface	Negative
30-46 cm	Negative
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative
Soils - Control Composites	
Surface	Negative
30-46 cm	Negative
46-61 cm	Negative
61-91 cm	Negative
91-122 cm	Negative

TABLE 139

CONCENTRATION OF MICROBES IN SLUDGES, SOILS, AND PLANTS[1] - 1976
COLUMBUS, INDIANA

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Sludge																	
Raw 7/13	5.91x10^9	ND	-	-	-	ND	-	-	-	0.77x10^6	+	+	+	8.0x10^7	+	+	+
Raw 11/29	1.08x10^{10}	ND	+	-	-	ND	+	-	-	0.32x10^4	+	+	+	1.60x10^3	+	+	+
Stab 7/13	4.00x10^{10}	ND	-	-	-	ND	-	-	-	1.1 x10^7	+	+	+	1.2x10^7	+	+	+
Stab 11/29	0.39x10^9	ND	+	-	-	ND	+	-	-	0.35x10^4	+	+	+	1.3x10^5	+	+	+
Plants																	
Treated - Leaf	1.00x10^{10}	ND	-	-	-	ND	-	-	-	330	+	+	+	2,700	+	+	+
Control - Leaf	2.74x10^{10}	ND	-	-	-	ND	-	-	-	ND	-	-	-	7,500	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

TABLE 139 (Continued)

Sample Description	Total Aerobic Bact per g Sludge	Salmonella				Shigella				Fecal Coliform				Fecal Streptocci.			
		Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed**	Total Org per g Sludge*	Presumptive**	Confirmed**	Completed*
Soils - Treated Composites	(10^6)													(10^2)			
Surface	130.	ND	+	-	-	ND	+	-	-	ND	+	-	-	130.	+	+	+
30-46 cm	10.1	ND	+	-	-	ND	+	-	-	ND	+	-	-	14.	+	+	+
46-61 cm	9.12	ND	+	-	-	ND	+	-	-	ND	+	-	-	1.2	+	+	+
61-91 cm	8.52	ND	+	-	-	ND	+	-	-	ND	+	-	-	1.0	+	+	+
91-122 cm	2.90	ND	-	-	-	ND	+	-	-	ND	-	-	-	.76	+	+	+
Soils - Control Composites																	
Surface	10.3	ND	+	-	-	ND	+	-	-	ND	+	-	-	13.	+	+	+
30-46 cm	7.59	ND	+	-	-	ND	+	-	-	ND	+	-	-	2.4	+	+	+
46-61 cm	3.80	ND	+	-	-	ND	+	-	-	ND	+	-	-	3.0	+	+	+
61-91 cm	18.8	ND	+	-	-	ND	+	-	-	ND	+	-	-	50.	+	+	+
91-122 cm	15.2	ND	+	-	-	ND	+	-	-	ND	+	-	-	2.5	+	+	+

[1] All results expressed on a dry weight basis.
*Values expressed as a power of 10 (i.e., 10^4).
**Observations reported as + or -.
ND = none detected.

439